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MASSACHUSETTS DEPARTMENT
OF PUBLIC HEALTH
DIVISION OF
DENTAL HEALTH

W A T E R F L U O R I D A T I O N

A TRAINING COURSE MANUAL FOR ENGINEERS, OPERATORS, AND TECHNICIANS

Commonwealth of Massachusetts

Office of Human Services

Department of Public Health

Division of Dental Health

Room 8M

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ABSTRACT

This training course should enable the local waterworks operator to maintain the proper fluoride level in drinking water. The fluoridation of public water supplies requires strict control of dosage rates for optimum dental health benefits. Accurate analytical determination of the fluoride level in the water is also essential.

DISCLAIMER

The use of trade names and commercial sources is for identification purpose only and does not constitute endorsement by the Public Health Service or by the U.S. Department of Health and Human Service or the Massachusetts Department of Public Health.

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Frederick P. Barker, Jr., P.E., Editor

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Chapter One

FLUORIDATION AND PUBLIC HEALTH

1.1 Definition

Fluoridation is actually the redistribution of a natural trace element by waterworks engineers in accordance with scientific and medical guidelines. Fluoride is present in small but widely varying amounts in practically all soils, water supplies, plants, and animals, and thus is a normal constituent of all diets. The highest concentrations in mammals are found in the bones and teeth. Almost all public water supplies in this country contain some natural fluoride.

Few public health measures have been accorded greater clinical and laboratory research, epidemiologic study, clinical trial, and public attention--both favorable and adverse--than the fluoridation of public water supplies.

1.2 History

In 1908, a Colorado Springs dentist, Dr. Frederick Mc Kay, became concerned over the fact that the teeth of many children in the community were mottled, which later investigations showed was caused by excessive amounts of fluorides in the local water supply. It was found that in towns using naturally fluoridated water, mottling appeared only when, as in Colorado Springs, the fluoride content of the water was abnormally high. It was also found that in these communities practically everyone had strong teeth and few cavities. Only a very small number of people had lost any of their teeth. It was concluded that when the fluoride content was one part per million, (ppm) there was no objectionable fluorosis (mottling) and optimal prevention of dental caries was achieved. In 1945, Grand Rapids, Michigan, and Newburg, New York, were the first cities to adopt controlled fluoridation.

Over the past 39 years continuous studies have been made of fluorides and fluoridation by the U.S. Public Health Service, State health departments, and nongovernmental research organizations. Since 1970 alone, there have been over 3,700 studies on fluoride. For a more comprehensive review of many of these studies, you are referred to the "Michigan Department of Public Health Policy Statement on Fluoridation of Community Water Supplies and Synopsis of Fundamentals of Relation of Fluorides and Fluoridation to Human Health." This synopsis contains an extensive list of references. There are many other very good reference booklets on fluoridation. Please write to the Centers for Disease Control in Atlanta, Georgia or the Massachusetts Department of Public Health for additional information.

All of these studies have upheld the effectiveness and safety of fluoridation. As of January 1, 1984, approximately 123 million Americans, or about 62% of those on public water supplies, consumed fluoridated water daily. Some 9.8 million of these are on naturally fluoridated supplies. In 1980, there were 8,278 communities which had adjusted the fluoride content of their water, and another 3,063 communities which received water naturally fluoridated at .7 ppm or higher levels. Some 24 million people in over 100 cities with populations of 50,000 or more, including Washington, D.C. and Chicago, have had adjusted fluoridation for more than 25 years. Approximately 70% of all cities with populations of 100,000 or more have fluoridated water. More than 22 States, the District of Columbia, and Puerto Rico provide fluoridated water to over one-half of their population. Massachusetts is one of those above referenced states with over 3.1 million people from 104 cities and towns drinking fluoridated water.

1.3 Causes of Dental Caries

Tooth decay is a complex process and all of the factors involved are not entirely understood. It is usually characterized by the loss of tooth structure (enamel, dentin, and cementum) as a result of destruction of these tissues by acids. Evidence shows that these acids are produced by the action of oral bacteria and enzymes on sugars and carbohydrates that are taken into the mouth. This action takes place beneath the plaque, which is an invisible film composed of gummy masses of microorganisms that adhere to the teeth. The bacteria are capable of converting some of the simpler sugars into acids, and the bacteria and enzymes acting in combination are capable of converting carbohydrates and more complex sugars into acids. The production of these acids is a result of the natural existence of bacteria and enzymes in the oral cavity.

The acids dissolve tooth enamel and initiate the process of tooth decay. As the enamel is dissolved, a cavity forms which usually becomes larger as the decay process continues. The dentin underneath the enamel may also be demaged by acid. If the protective covering of enamel and dentin are destroyed, the pulp may be exposed to infection by bacteria.

The highest tooth decay activity is found in school children. It begins in early childhood and reaches a peak in adolescence, but diminishes during adulthood.

1.4 Dental Benefits

Nearly everyone is this country is attacked by dental caries, the most prevalent chronic disease of man. It is truly universal. More than 98 out of 100 Americans experience some tooth decay by the time they reach adulthood. By age 17, the average American will have ten decayed, missing or filled teeth. The average Massachusetts 17-year-old has 14 tooth surfaces affected by decay-30% higher than the national average. Much of the pain and expense of dental decay can be prevented through fluoridation. No other public health measure is as effective in building decay-resistant teeth and it is available to all without regard to education or socio-economic background.

The effect of fluoridated water ingested during the years of tooth development has been amply demonstrated. The evidence is irrefutable that fluoride, at the optimum concentration in potable water, will reduce dental caries by up to 70 percent among children who ingest this water from birth. The benefits continue into adult life. Stronger teeth result in fewer caries, requiring fewer and less extensive fillings, fewer extractions and fewer artificial teeth.

The reduction in DMF (decayed, missing, filled) teeth in children has been well publicized. Less publicized have been the continuing benefits. Various studies in fluoridated communities over the last thirty years have shown a dramatic increase in the number of teenagers completely caries-free. It has been demonstrated that even teenagers without lifetime exposure have realized benefits from adjusted fluoridation and that the benefits increase among those with life-time exposure. Conservative estimates indicate that 20 percent of the teenagers in a fluoridated community will be caries-free. This is about six times as many as are caries-free in a fluoride-deficient community.

Fluoridation thus enhances the beauty of the teeth, makes them more impervious to bacterial acids, and substantially reduces bills for restorative dentistry. The benefits of fluoridation last for a lifetime if one continues to consume fluoridated water. It reduces the number of tooth root caries which are likely to occur as the gums recede exposing tooth root surfaces. There is also some evidence to show that higher levels of fluoride strengthen the bones of older people, thus reducing the incidence of bone fractures, and may play a role in reducing periodontal disease.

1.5 **Systemic and Topical Effects of Fluorides in Drinking Water**

In general, when water containing fluoride is drunk, a small amount (20%) is retained by fluids in the mouth and will be incorporated onto the tooth by surface uptake (topical effects). The greater part (80%) of the fluoride utilized goes into the stomach and is rapidly absorbed by simple diffusion through the walls of the stomach and gut. It enters the blood plasma and is rapidly distributed throughout the body, including the teeth (systemic effect). Because of the systemic effect, the fluoride ion is able to pass freely through all cell walls and thus is available to all organs and tissues of the body. Distributed in this fashion, the fluoride ion is available to all the skeletal structures of the body in which it may be retained and stored in proportions which, generally speaking, increase with age and with intake.

The bones, teeth, and other parts of the skeleton tend to attact and retain fluoride. The soft tissues do not retain fluorides. It is correctly stated that fluoride is a "bone seeker." About 96% of the fluoride found in the body is deposited in the skeleton of the body.

As the teeth are part of the skeleton, the incorporation of fluoride in the teeth is basically similar to that in other bones. It is most rapid during the time of the child's formation and growth. This time period is roughly from the 4th month of pregnancy to the 10th year of the child's age. The 8th year probably marks the end of the maximum rate of incorporation of fluoride in the teeth. Erupted teeth differ from other parts of the skeleton in that once they are formed, with the exception of the dentine (inner part of the tooth) and the root, there is very little cellular activity. Thus, there is not as much change in the fluoride levels in the teeth after they are formed. Hence, it is important that children drink the proper amount of fluoridated water during the early development of the permanent teeth, usually before they start school

As is true with the bones, the fluoride concentrated in the teeth has a direct relationship with the level of fluoride in the drinking water and with the age of the subject. But, not being subject to internal repair by the body, the teeth do not tend to lose fluoride by reabsorption except, of course, in the root structure. The amount of fluoride in the teeth varies as widely as the fluoride in the other parts of the skeleton, from several hundred to several thousand parts per million (ppm).

In summary, there are two ways that fluoride in drinking water is incorporated in the teeth. The first method is called topical uptake, denoting a surface ionic exchange, and about 20 percent of the total fluoride used by the body is obtained in this manner. The second method is called systemic uptake, denoting incorporation of the fluoride ion through absorption in gut and diffusion into the blood stream and hence to the teeth. Eighty percent (80%) of the fluoride used by the body is obtained because of systemic uptake.

1.6 Alternatives to Water Fluoridation

While there are other ways to provide the benefits of fluoride besides the fluoridation of municipal water supply systems, one point must be kept clearly in mind. Municipal water fluoridation is by far the most cost-effective means available for reducing the incidence of caries in the community. This conclusion is based on the mass of evidence demonstrating the efficacy of the measure, and on the most current information on costs of implementing fluoridation. School fluoridation is another way to provide the benefits of water fluoridation, but should not be considered as an alternative to community water fluoridation. It it not used in Massachusetts but has been used in other states in remote rural areas without a community water supply.

A new preventive method has recently been found to be effective against cavities. Children between the ages of 5-17, are prime targets for tooth decay. While fluorides are the most effective and least expensive way of preventing decay, some 54 percent of the cavities found in children's teeth occur on the chewing surfaces where fluorides are least beneficial. Research has proven that by using dental sealants in conjunction with fluorides, children receive maximum tooth protection.

Dental sealants are safe and effective plastic films which are applied by dental professionals to the chewing surfaces of children's teeth. By sealing off the tooth's surface, sealants can prevent food and bacteria from being trapped, thus preventing the initiation and progress of decay. However, sealants should be used only in conjunction with water fluoridation. If only sealants are used, decay can strike the unprotected areas and work under the sealant.

In general, there are four alternatives to water fluoridation, which use either the topical or the systemic uptake method: See section 1.9 on page 1-14.

A. Topical Uptake Methods

1. Topical application of sodium fluoride
2. Fluoride gels
3. Fluoride mouthwashes

B. Systemic Uptake Method

Fluoride tablets

TABLE 1-1
COMPARISON OF EFFECTIVENESS OF ALTERNATIVES TO FLUORIDATION*

Procedures	Number of Cavities Prevented**	Cost/Cavity
Municipal water fluoridation	500,000	$ .20
School water fluoridation	111,110	.90
Supervised application of paste or rinse in school	55,555	1.82
Professional application of topical fluoride	25,600	3.90
Supervised distribution of fluoride tablets in school	16,542	6.06
Individually prescribed fluoride tablets or drops, assuming full compliance	10,000	10.00

*Estimates from Dr. Charles Gish, Director, Division of Dental Health, Indiana State Board of Health which were published in June 1978 in the Proceedings of a workshop at the University of Michigan.
**Number of cavities prevented per $100,000 spent.

TABLE 1-2
TOPICAL FLUORIDE APPLICATIONS*

Applications	No. of Applications	Rank of Use	Percent Reduction in Number of Cavities
1. Professionally Applied			
a. 2.0% NaF liquid	4/yr	2nd/3rd (tie)	35
b. 1.23% APF liquid** or gel	1/yr	4	35
c. 8.0% Stannous Fluoride	1/yr	7th/8th (tie)	20
2. Self-Applied			
a. 0.2% NaF Rinse	Weekly	1	25
b. Supervised brushing with 0.6% APF	5/yr	5	20
c. Supervised brushing with 9.0% Stannous Fluoride	2/yr	2nd/3rd (tie)	25
d. Toothbrushing at home with 0.1% fluoride dentifrice	Daily	6	20
e. Daily APF-Gel, 0.5% at home in trays	Daily	7th/8th (tie)	80

*Heifetz, Stanley B. "Cost-Effectiveness of Topically Applied Fluorides." Workshop on Preventive Methods in Dental Public Health. Ann Arbor, Mich., June 5-8, 1978.
**APF is Acidulated Phosphate Fluoride.

While the topical uptake methods can be used in conjunction with the fluoridation of a municipal water supply system, the systemic uptake method (tablets) should never be used with municipal or school fluoridation. The cost and the effectiveness of these alternatives vary, of course, as shown in Table 1-1 on page 1-5.

The systemic fluoride supplements require daily administration and may be either tablets or drops. They may be either plain sodium fluoride (NaF) or combined with vitamins. The annual cost per child in 1980 was $10.20 for NaF with vitamins.

Topical fluoridation applications may be professionally applied or selfapplied. Table 1-2 on page 1-5 ranks these methods according to use and shows the percent reduction in DMF (decayed, missing and filled) teeth.

Stannous fluoride solution is now rarely used in professional application. The most common method in professional applications, by far, is the APF gel. Is the most common method of self-applied topical fluoride applications is the 0.2% or 2,000 ppm NaF weekly rinse.

1.7 Dental Fluorisis

Dental fluorosis is defined as the whitish to brownish spots seen on teeth in high fluoride areas. It has been clearly established that high levels of fluoride in the drinking water will cause fluorosis (or "mottled enamel" as it is sometimes called.)

In the 1930's, Dr. H. Trendley Dean, the first director of the National Institute of Dental Research, was assigned to explain the relationship between mottled teeth and low incidence of dental caries. From this search came the recommendation for water fluoridation at the various optimum levels. To document the relationship between mottled teeth and the incidence of dental caries, Dr. Dean developed the "Dean's Index of Dental Fluorosis." The index established a method of comparing various stages of fluorosis.

Dr. Dean's Index and his 21 city study were used to determine the optimum levels of fluoride in the drinking water. Dr. Dean's Index shows that there is very little mottling at fluoride levels of 2.0 ppm or lower. Even this mottling, which causes formation of whitish opaque, is not unattractive. At over 3.0 ppm of fluoride, the brown strain effect becomes noticable. (Figures 1-1 and 1-2 on page 1-7).

1.8 The Opponents of Fluoridation

Although community water fluoridation has been proven to be both safe and the most cost-effective method to prevent dental caries; a small percentage of the population continues to oppose its introduction into community water systems. When fluoridation is being considered for adoption by a community, persons opposed to fluoridation often introduce charges or allegations that attempt to refute the benefits, safety and efficacy of this proven public health measure. Since many of these charges will have to be answered by the State fluoridation engineer, a sample of the charges are presented in this chapter. They are divided into two groups: 1) engineering charges, and; 2) medical/legal charges.

Here are the charges and the facts that relate the engineering aspects of fluoridation:

FIGURE 1-1
DEGREE OF MOTTLED ENAMEL AND FLUORIDE
CONCENTRATION IN WATER

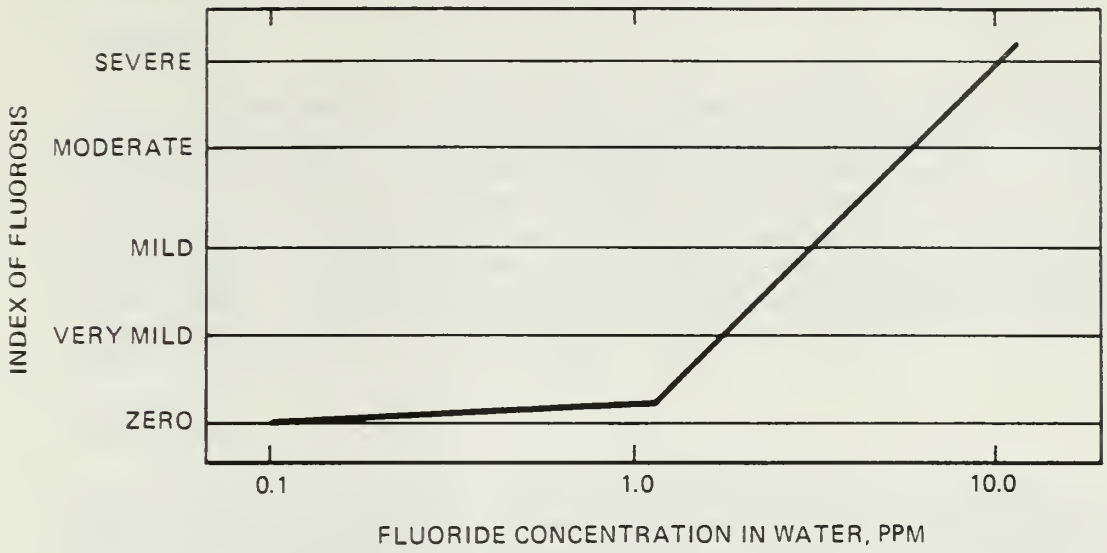
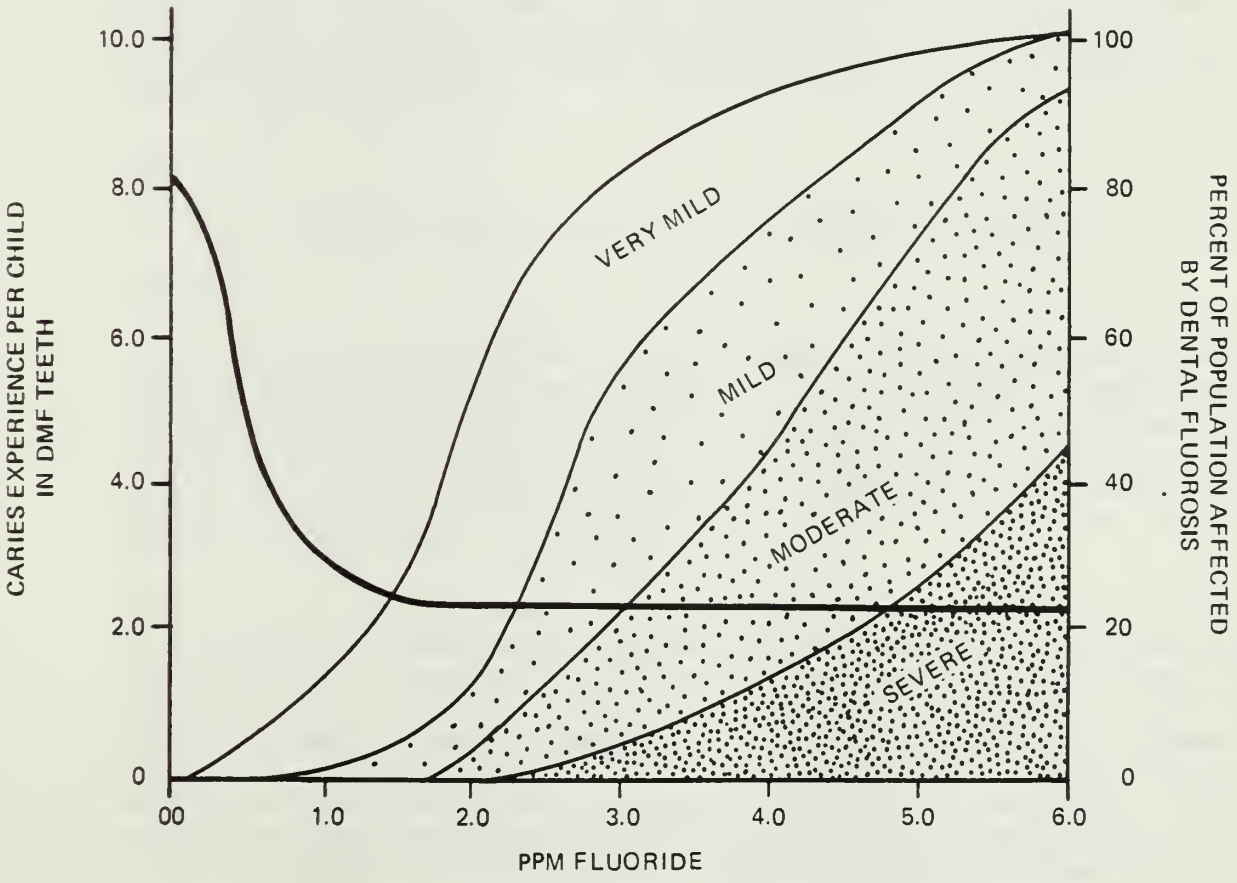


FIGURE 1-2
DENTAL CARIES AND DENTAL FLUOROSIS IN RELATION TO
FLUORIDE IN PUBLIC WATER SUPPLIES



1. **THE CHARGE:**

Natural fluoridation is different from controlled fluoridation.

THE FACT:

There is absolutely no difference. No matter where the fluoride comes from, the fluoride ion in the drinking water is the same. The element fluorine is made up of atoms that have a definite structure. When fluorine combines with another element, each fluorine atom gains one electron and the new substance is called fluoride. In a water solution, these fluoride particles tend to dissociate as separate charged particles called ions. The fluoride ions have completely different properties from fluorine. But, no matter which group of minerals the fluoride comes from, the fluoride ion is the same.

2. **THE CHARGE:**

Fluoridation is wasteful. Less than one-tenth of one percent of the water is drunk by children. The remaining 99.9 percent is used for sanitary and industrial purposes, fighting fires, washing streets, sprinkling lawns, etc.

THE FACT:

True. But on this argument, chlorination and all other water treatment processes are also wasteful. Fluoridation is beneficial to adults as well as children. Obviously, one cannot fluoridate only that part of the water drunk. The fluorides must be added to the whole supply. Even with this admitted waste, the cost of approximately 50 cents per year per person is little enough to spend for this proven method of preventing tooth decay in children.

3. **THE CHARGE:**

There is a danger that a whole town will be over-fluoridated.

THE FACT:

Such a danger is non-existent. In this country, the apparatus, chemicals and mode of operation are so arranged that it is virtually impossible to administer a dangerous dose to a whole community. The type of pump used for operating near its maximum capacity, would add fluoride solution at the rate of only 2 ppm. Moreover, the pump is frequently calibrated, and the fluoride content of the water is checked routinely, so that any deviation from the desire level is immediately seen.

Nevertheless, it is suggested by some that either by accident or design it is possible to have mass poisoning of a community. Though such ideas are unrealistic, they are entertained by some members of the community and therefore the logistics of the suggestion need to be examined. The minimum fatal dose for a human is approximately 2 grams of fluoride. It takes about 19 lb. of sodium fluoride or 14 lbs. of sodium silicofluoride to fluoridate 1 million gallons of water at 1 ppm. To fluoridate 10 million gallons of water would require 190 lbs. or 140 lbs., respectively. To raise the fluoride concentration to a level where the minimum fatal dose (2 grams) could be consumed in say, a 10 oz. glass of water, it would be

necessary to add to the same water supply approximately 700 tons of sodium fluoride or 500 tons of sodium silicofluoride at one time. The danger would probably be greatest in larger systems that use dry feeders. The hopper capacity of the fluoridator (dry feeder) is designed to be limited to two days supply (about 50 lbs), but even if one week's supply was added at one time, it would still be about one five-hundredth of the quantity required for the minimal fatal dose. Obviously, under the circumstances, it is impossible for 700 tons of fluoride chemical to be put into the water at one time

4. **THE CHARGE:**

An accident in the water plant might cause a harmful overdosage of fluorides.

THE FACT:

Fluoride feeders are designed to stop if there is an accident or a malfunction. Besides, a year's supply of fluoride would have to be added in a single day to produce harmful effects. That is many times the amount of fluoride the water plant usually has available for fluoridation.

5. **THE CHARGE:**

Fluoridation causes corrosion in the water lines.

THE FACT:

Allegations that fluoridation is the cause of corrosion in water systems continue to be circulated despite refutations by competent authorities such as the American Water Works Association and the National Association of Corrosion Engineers. Corrosion by potable water is related primarily to dissolved oxygen concentration, pH, water temperature, alkalinity, hardness, salt concentration, hydrogen sulfide content, and the presence of certain bacteria. The fluoride ion itself is unrelated to corrosion at concentrations found in potable water at or near the optimum level. Under special conditions of water quality, a small increase in the corrosivity of potable water that is <u>already</u> corrosive may be observed after treatment with alum, phosphates, chlorine, hydrofluosilicic acid, or sodium silicofluoride. The very slight increase in corrosivity by depression of pH resulting from these treatments occurs in potable waters with little buffering capacity (alkalinity less than about 10 mg/l as calcium carbonate). (It should be noted that this is due to hydrogren (H^+)ions and not fluoride (F^-)ions.)

6. **THE CHARGE:**

Fluoride adds taste, color, or smell to the water supply.

THE FACT:

This is not true. Color, palatability, taste, and smell are not affected by the addition of fluoride at a concentration of 1 ppm. Water supplies, of course, vary in regard to their content and there is no such thing as pure water in the absolute sense. Also, other materials can add taste and/or smells to a water supply system, especially total dissolved solids.

Using distilled water as a test medium is not an exact substitute for water in which there may be anywhere from 100 to 1,500 ppm of dissolved solids. However, using distilled water, an experiment showed that 50% of 280 subjects tested failed to distinguish any difference between distilled water and distilled water fluoridated at 133 ppm. In another experiment, out of 187 male dental students, only eight said they could detect fluoride in 10 ppm fluoride in distilled water. It was thus concluded that a fluoride concentration of 1.8 ppm would be tasteless in distilled water and that the average person would be unable to detect any taste at 10 ppm. It is strongly suggested that the taste threshold would be even higher in normal (i.e., undistilled) water.

7. **THE CHARGE:**

The hardness of water makes the introduction of fluoridation difficult.

THE FACT: There is no truth to this charge. Calcium and magnesium can reduce the solubility of fluorides but this effect is negligible with the concentration present in natural waters. It may be necessary to soften water used to make a fluoride solution to enable it to be added homogeneously to the supply but this presents no difficulty.

8. **THE CHARGE:**

Although fluoride may be added at uniform rate at the source of water supply, there is a likelihood of the fluoride tending to form pockets in water pipes which would give rise to uneven concentrations.

THE FACT:

This is not true. At the concentration of 1 ppm fluoride (F), the fluoride is completely soluble and will not be precipitated out of solution, even in hard water. The concentration of fluoride at the plant tap will be carried throughout the distribution system, but if a change in the concentration occurs at the plant there will be a time lag before the change reaches outlying parts of the distribution system. The time lag depends on the length of pipe through which the water has to pass. But, "pockets of fluoride" do not occur in the distribution system.

9. **THE CHARGE:**

There are alternative, inexpensive methods which can be used by families who believe in the value of fluoridation, such as a home fluoridation unit.

THE FACT:

There is no reasonable alternative to community fluoridation. It is impractical and much more expensive to attempt to have each home have their own fluoridation system. The operation and maintenance problems are difficult for the average home owner to handle.

10. **THE CHARGE:**

Fluoridation is promoted by the big chemical companies which make huge profits out of it.

THE FACT:

This is a false statement. Fluoridation represents only one ten-thousandth of the business of the chemical industry.

Here are some of the medical/legal charges made by those opposed to the fluoridation of community water supply systems.

11. THE CHARGE:

Fluoridation causes cancer.

THE FACT:

Early in 1975, the National Health Federation issued information alleging a relationship between fluoridation and cancer. Their allegations have been repeatedly refuted, both by separate reviews of their work and by independent studies, not only in the United States but in several other countries. Reviews have been conducted by the National Cancer Institute of the National Institutes of Health. Independent studies conducted in the U.S. by the National Cancer Institute, the National Heart, Lung, and Blood Institute, and the Centers for Disease Control found no relationship between fluoridation and cancer mortality. Recent studies reported on populations in Australia, England, and Canada, encompassed 79 groups of municipalities and covered approximately 20 years (1954-1973). These studies concluded that no appreciable differences in death rates from all types of cancer or any specific tumor site were indicated between fluoridated and non-fluoridated municipalities over this period. Nor were any significant differences apparent between death rates from all types of cancer when compared within the same group of municipalities prior to and after fluoridation.

12. THE CHARGE:

Fluoridation causes heart diseases, diabetes, and liver and kidney ailments.

THE FACT:

Studies made in 64 cities (32 of which have used naturally fluoridated water for generations, and 32 without fluoridation) show no significant difference in the mortality rates from these diseases. These findings have been confirmed by other studies in Illinois, New England, Texas, and New York.

13. THE CHARGE:

Fluoridation is a mass medication.

THE FACT:

Fluoridation is not a medicine. It does not treat or cure anything. It is a nutrient which prevents dental decay. Like other minerals in the diet, fluoride helps the body to resist disease. And dental decay is a serious disease.

14. THE CHARGE:

Fluoridation is unconstitutional and illegal invasion of individual rights.

THE FACT:

Over the years the legality of fluoridation has been tested repeatedly. Courts in over one-half of the States have heard fluoridation cases, and the constitutionality of fluoridation has been upheld by State Supreme Courts in over a dozen States. In addition, at least eight times, cases have been taken to the United States Supreme Court, where the court has declined to hear these cases because no substantial federal constitutional question was involved. To date, no final decision has ever been made that was unfavorable toward fluoridation regardless of the charges presented.

15. THE CHARGE:

Fluorides in drinking water can produce allergic reaction.

THE FACT:

Fluoride in the concentration recommended for dental health does not cause such reactions. The American Academy of Allergy conducted a review of clinical reports of possible allergic responses to fluoride. The Academy found no evidence of allergy or intoloerance. Following completion of the study, the Executive Committee of the Academy unanimously adopted the following statement: "There is no evidence of allergy or intolerance to fluorides as used in the fluoridation of community water supplies."

16. THE CHARGE:

The cumulative effect of a fluoridated water supply will damage irreparably the tissues and bones of the body.

THE FACT:

The effect of fluoridation is non-cumulative. A minute part is deposited in the bones and teeth; the remainder is rapidly excreted through the kidneys. It is true that the bones and teeth will accumulate fluoride over long periods of time. This is not a problem, but rather a beneficial result.

17. THE CHARGE:

Fluoride is used as rat poison.

THE FACT:

True. Fluoride was used as a rat poison in the past. It no longer is used as such because it was not very effective. But no one has ever questioned that large doses of fluoride are

toxic. However, it is essential to emphasize two completely different aspects of fluorides. One aspect concerns the serious toxic effects from massive doses of extremely high levels of fluorides. The other aspect concerns evaluation of the effects of trace amounts of fluoride in the drinking water. The implication that fluorides in large doses and in trace amounts have the same effect is completely incorrect. Many substances in common use are very beneficial in small amounts, but may be harmful in large doses, for example, table salt (sodium chloride) or chlorine.

The list of charges, whether they relate to engineering, medical, legal or other questions, could go on indefinitely. Some of the more common questions that may arise are presented for the State fluoridation engineer/technician or the water treatment plant operator. There are several studies and reports on the charges against fluoridation that are very complete. If additional information is desired on any charge or information on a charge not covered in this manual, please refer to Fluoridation Facts, a publication of the American Dental Association or other similar publications.

It is unfortunate that irrelevant, unreplicated, or refuted research is purposefully presented to the detriment of the health of this nation's children. It is also unfortunate that misinterpretation of actions in foreign countries and out-of-context statements continue to circulate and create unnecessary fears. For every report which casts doubt on fluoridation, there are innumerable reports attesting to its safety and efficacy. It is not surprising that some differences of opinion among scientists and professionals in research and medicine may occur. What is surprising, however, is their almost universal agreement on the safety and effectiveness of fluoridation. Fluoridation is not a controversy in any scientific sense. There are few public health measures which have had the scientific endorsement and broad base of research which supports its use as does fluoridation.

Fluoridation has the support of the U.S. Public Health Service and, in the more than 39 years that the program has been in effect, there has been no valid evidence of harm to anyone from drinking optimally fluoridated water. There is no valid reason why the benefits of fluoridation should be denied to the citizens of any community.

1.9 RECOMMENDED USE OF SYSTEMIC AND NON-SYSTEMIC FLUORIDES
MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH - July, 1982

Systemic — The ingestion of a substance that affects the body as a whole. An internal method for obtaining fluorides by swallowing fluoridated water, some fluoride mouth rinse or dietary fluoride supplements in the form of tablets, pills or drops that have been prescribed by a physician or dentist.

Non-Systemic — The local or topical use of a substance. The direct application of professionally applied fluorides to the teeth, the use of a fluoride tooth paste, a fluoride mouth piece and most fluoride mouth rinses. None of these topical methods for obtaining fluoride are meant for internal use and thus are not to be swallowed.

I. Use of Fluoride in Non Fluoridated Communities.

	Type of Fluoride	Systemic/Non-Systemic	Recommendation for Use
A.	Fluoride mouth rinse	Non-Systemic	Yes
B.	Fluoride tooth paste	Non-Systemic	Yes
C.	Topical applications of fluoride	Non-Systemic	Yes
D.	Dietary fluoride pills, tablets drops taken internally	Systemic	Yes
E.	Fluoride mouth rinse	Systemic	No*

*When taken in addition to fluoride dietary pills, tablets, or drops ingested internally.

II. Use of Fluoride in Communities With Public Water Supply Fluoridation.

	Type of Fluoride	Systemic/Non-Systemic	Recommendation for Use
A.	Fluoride mouth rinse	Non-Systemic	Yes
B.	Fluoride tooth paste	Non Systemic	Yes
C.	Fluoride Mouth Rinse	Systemic	No
D.	Dietary fluoride supplements in the form of tablets, pills, drops	Systemic	No

III. Optimal of Systemic Dietary Fluoride Supplementation by Age in Non-Fluoridated Communities and Communities Where the Natural Fluoride Concentration is less than 0.3 ppm.[1]

Age	Fluoride Dosages in Milligrams
0-2 years	0.25 mg. of fluoride daily
2-3 years	0.50 mg. of fluorides daily
3-13 years	1.0 mg. of fluoride daily

Note: In those few isolated communities where the natural fluoride content of the water is above 0.2 ppm or greater downward adjustments by age must be made in the fluoride dosage.

1. American Dental Association, Prescribing fluoride Supplements, In accepted dental therapeutics, ed 38. Chicago, American Dental Association, 1979, p. 319,-322

1.10 LEGAL ASPECTS OF FLUORIDATION

A. History of Fluoridation Legislation in Massachusetts

Before 1958, the authority to fluoridate the domestic water supply was vested in its local board of health or equivalent agency. A letter of opinion from the Attorney General to the Commissioner of Public Health on January 20,1953, responsed affirmatively to the questions whether: 1) the laws of the Commonwealth relating to public water supplies permit the addition of fluorides as a dental caries prophylactic to the water supply, and 2) the Department of Public Health has authority to approve the application of fluoridation to the public water supplies if so requested.

Fluoridation had, however, been undertaken before 1958 in several Massachusetts communities:

Ashburnham	Danvers	Middleton	Shrewsbury
Athol	Essex	Salem	Templeton
Beverly	Hamilton	Scituate	Topsfield
Cohasset	Hingham	Seekonk	Winchester
Concord (Kalmia Woods)	Hull	(Water District)	
	Medway	Sharon	

In 1958, the Legislature passed a stature prohibiting the institution of fluoridation without prior voter approval via a referendum. In 1962, a legislative amendment made it possible for a community, on petition of five percent of its registered voters, to obtain a referendum seeking the discontinuance of fluoridation.

In 1963 the Supreme Judicial Court in the case of Scott v. Board of Election Commissioners of Newton (346 Mass. 388) ruled that a referendum vote on fluoridation would be advisory only, and the authority to rule in this issue rested solely with the appropriate municipal officers.

Restricted by these laws, only 7% of the Commonwealth's total population received fluoridated water. As of January 1, 1969, Massachusetts was ranked among the lowest of the states benefiting from water fluoridation.

A law signed on July 9, 1968 (Chapter 548 of the Acts of 1968), ruled that these compulsory referenda laws (General Laws Chapter 41 B and 41 C of Chapter 40 of the General Laws) be repealed. The Department of Public Health was directed, to recommend "such methods as its opinion was advisable to reduce or limit the prevalence of dental caries and other diseases and defects".

Under this law, if the Commissioner decides that the fluoride content of any domestic water supply is not at an optimum level for dental health, she/he is to notify the local board of health of these findings. All Massachusetts supplies are deficient in fluoride and notifications was given to each local board of health in the Commonwealth shortly after enactment of the law.

B. THE MASSACHUSETTS FLUORIDATION LAW

Chapter 111 of the general Laws, Section 8C, as amended:

"Local Health Boards May Order Fluoridation of Water Supplies; Exception; Submission of Question to Voters, etc.

"The department in taking cognizance of the dental health of the people of the commonwealth shall recommend such methods as in its opinion are advisable to reduce or limit the prevalence of dental caries and other dental diseases and defects. If the commissioner determines that the fluoride content of the public water supply for domestic use in any city, town or district is not at optimum level for sound dental health, he shall notify the local board of health of his findings. Such board of health, after making such inquiry and other use of the consulting services of the department or elsewhere as it chooses, shall, if it considers doing so in the best interest of the inhabitants of the city, town or district within its jurisdiction, order the upward adjustment of the fluoride content of the water supply available for domestic use in the city, town or district. No such order shall be effective until ninety days after it has been published in a newspaper having a general circulation in such city or town, or until favorable vote has been taken in accordance with the provisions of the section, whichever occurs later.

The provisions of this section shall not apply if two or more cities or towns are supplied water from the same source, if such supply to each city or town cannot be treated independently and if the majority of the boards of health representing such cities and towns have voted not to accept such recommendation; provided, however, that any such city or town desiring to adjust upward the fluoride content of the water consumed within its own jurisdiction may comply with the order by the installation of proper equipment that will comply therewith if it does not interfere with the water supply of said other cities or towns."

"In any city, town or district where the board of health has ordered the upward adjustment of the fluoride content of the water supply under the provisions of this section, upon petition of ten percent of the registered voters of said city, town or district, filed in the office of the city or town clerk, as the case may be, within ninety days of the publication of such order, the following question shall be placed upon the offical ballot to be used at the next regular city election or for the election of town officers at the next annual town meeting (or at a biennial state election, whichever occurs first, but not earlier than sixty days following the date of filing the petition with the city or town clerk): Shall the public water supply for domestic use in (this city) (this town) be fluoridated?, or in district the following question shall be placed before the next annual meeting of the inhabitants of the district: - "Shall the public water supply for domestic use in this district be fluoridated? if the majority of votes in answer to said question is in the negative the water supply of such city, town or district shall not be fluoridated, and the question of fluoridation of such water supply shall not be ordered again by the board of health for a period of at least two years from the date of such vote. (Added by 1968, 548, s. 1, approved November 9, 1971, effective 90 days thereafter; and by St. 1976, 129, approved May 24, 1976.)"

After an Order Has Taken Effect

The board of health should confer with water officials and other concerned municipal officials to inform residents about fluoridation and to plan the implementation of the order.

It is the responsibility of all officials involved to proceed with arrangements for funding, preparation of engineering plans and specifications, and submission of the same to the Massachusetts Department of Environmental Quality Engineering for approval, and finally to purchase, install and operate the fluoridation facilities under supervision of the Massachusetts Department of Environmental Quality Engineering.

Authority of Local Board of Health

The basic authority of the local board of health shall not apply if two or more cities or towns are supplied water from the same source, providing two qualifications are met:

1. If the supply of that particular city or town cannot be fluoridated independently.

2. If the majority of the boards of health representing such cities or towns have voted not to accept such recommendations.

However, any city or town may fluoridate its water supply if doing so does not interfere with the water supply of any other city or town.

Water Companies

A privately-owned (or investor-owned) water company is subject to the local board of health's order to the same extent as a public water department.

Water Districts

Water districts are established by special acts to provide water supply within a designated area. Most districts - but not all - serve a portion of a city or town. Their function and authority are similar to those of a city or town water department. Water districts are subject to local boards of health's fluoridation order to the same extent as a water department.

A 1972 opinion by the Attorney General states that the Metropolitan Water District, which comprises 33 cities and towns, is obliged to commence fluoridation when a majority of the boards of health representing such cities and towns ordered fluoridation, and the time within which referendum petitions might have been filed passed without such action having been taken or any required referenda were in favor of fluoridation.

Discontinuing Fluoridation

A board of health has the authority to order the discontinuance of fluoridation at any time if it believes the discontinuance to be in the best interest of the citizens of the community.

C. Commentary on the Fluoridation Law

Section 8C, Chapter 111 spells out distinctly how a water supply may be fluoridated when a local board of health deems it advisable.

Basic Authority

In essence the law directs the Commissioner of Public Health to determine the fluoride content of a water supply, and, if it is not at an optimum level, to notify the local board of health.

The local board of health having been so notified, if it considers doing so to be in the best interest of the inhabitants of the city, town, or district, may order the upward adjustment of the fluoride content of such water supply.

Ordering Fluoridation

To comply with the provisions of the law, a board of health ordering fluoridation is required to publish (advertise) its order as a legal notice in a newspaper with circulation in the city or town. A vote of the board to fluoridate does not fulfill this requirement, nor does publication of such a vote as a news item. An official vote of the board and a formal legal notice are required.

Example of a legal Notice of Board of Health Order

The Commissioner of the Department of Public Health, Commonwealth of Massachusetts, has determined the fluoride content of the public water supply for domestic use in the town of (x) is not at optimum level for sound dental health and has so notified this board of health of his findings.

The board of health of the town of (x), after making sufficient inquiry of the matter, considers an upward adjustment of the fluoride content of the water supply available for domestic use in the town of (x) to be in the best interest of the inhabitants of the town.

Accordingly, it is hereby ordered under the authority of Chapter 111, Section 8C of the general laws as amended, that an upward adjustment to the optimum level for sound dental health be made in the fluoride content of the water supply available for domestic use in the town of (x).

Provisions for Referendum

In any city, town or district where the upward adjustment of the fluoride content of a water supply has been ordered, upon petition of ten percent of the registered voters filed with the local clerk's office within 90 days of the publication of such order, the question may be placed on the ballet at the next regular city election, whichever occurs first, but not earlier than 60 days following the date of filing the petition with the city or town clerk, whether the water supply should be fluoridated. If the majority of votes are against fluoridation, it shall not be fluoridated, and no order of fluoridate may be entered for a period of two years from the prior vote. Fluoridation may not be implemented, during the 90 days following the board's order, and, when a petition is successfully filed, until a favorable vote is taken.

Financing

Once a lawful order to fluoridate has been issued and the time has passed for initiating a referendum or a favorable vote has been taken on a referendum, the appropriating authority of the town or city involved must appropriate the required funds.

The Supreme Judicial Court so held in the case of Board of Health of North Adams v. Mayor or City Council of North Adams, Mass. Adv. Sh. (1975) 2708. As that court notes (at p. 2725), the power exists in the local health board to "order" fluoridation. "The word order would be inappropriate if it did not comprehend the power to compel appropriating."

Lobbying and Elections

Any group of five or more persons who favor or oppose the adoption or rejection of a fluoridation referendum and who intend to expend any money must file with the secretary or the city or town clerk, depending on the nature of the election, and organizational statement and other reports required by law. These requirements are somewhat complicated and should be followed very carefully.

Chapter Two

FLUORIDATION ENGINEERING

2.1 Water Fluoridation Practice

2.1.1 Purpose

Fluoridation is the deliberate adjustment of the fluoride content of public water supplies to a level of approximately one part per million for the purpose of reducing tooth decay. Generally, there is a 67 percent reduction in the rate of tooth decay in children up to the age of 16. It has been estimated that fluoridated water systems, if available throughout the country, could in time reduce the national dental bill by one-half. The benefits expected from fluoridation then are considerable. Fluoridation is the second most cost-effective public health measure in the United States. (The first is immunization for polio.)

2.1.2 Present Status of Fluoridation

According to the 1980 census, approximately 106 million citizens, representing more than 8,000 water systems throughout the Nation are receiving the benefits of optimally adjusted fluoridated water. An additional 9.8 million people in 3,000 places are drinking water with naturally occurring fluoride (0.7 ppm or more). Today, after thirty-five years of fluoridation, more than 50 percent of the Nation's total population is served by fluoridated water supply systems. It is expected that the number of people on adjusted fluoride water will increase in the next few years.

2.1.3 General Methods of Feeding Fluorides

While the engineering details of fluoridation will be explained later, the general methods of feeding fluorides will be given now. There are really only three common methods of adjusting the fluoride level in a drinking water supply system:

1. Chemical dry feeder with a dry, fluoride compound (sodium silicofluoride).

2. Chemical solution feeder with a liquid fluoride compound (hydrofluosilicic acid) or with a prepared solution of a fluoride compound (sodium fluoride).

3. Fluoride saturator, a chemical solution feeder with a fluoride compound (sodium fluoride).

The first two methods are commonly used to feed other chemicals into the water at a water treatment plant. The saturator is a unique method for feeding fluoride and can be considered a special application of the chemical solution feeder method.

2.1.3.1. Community Systems

All three of the above methods of feeding fluoride are common in community water supply systems. In general, the very large systems will use the first two methods while the smaller systems will use either the acid feeder or the saturator. The primary factors in the selection of the fluoridation system should be the chemical cost, equipment cost, room to house the equipment, water usage (population), type of operating personnel available and the preference on that part of the owner and

consulting engineer. There is no one specific type of fluoridation system which is solely applicable. In general, the smaller systems should consider the cost of the equipment as the major factor in their decision, while larger systems should consider the cost per pound of the fluoride chemical as the major factor.

2.1.4. Summary

In summary, fluoridation is simply a process of adding a naturally occurring element to drinking water. Communities do this to prevent tooth decay, using guidelines developed by scientific and medical research.

Community fluoridation is supported by government officials, the U.S. Public Health Service, the American Dental Association, the American Medical Association, the World Health Organization, the American Water Works Association, and virtually every scientific and professional organization in the health field.

Fluoridation is safe. It's economical. It's effective. There is no substitute which can prevent two out of every three cavities.

The effectiveness of fluoridation depends on how consistently the water treatment operator maintains the optimum fluoride concentration. He holds the key to better dental health. As has been stated by Dr. Joseph M. Doherty, Director, Division of Dental Health, Virginia Department of Health:

> "We must recognize the <u>operator</u> as being part of that professional team. He should be recognized, because I think he does more to prevent decay than all the dentists in that community can do in their lifetime."

2.2. Fluoride Chemicals

2.2.1 Introduction

Fluorine, a gaseous halogen, is the thirteenth most abundant element found in the earth's crust and in the human body. Fluoride is never found in a free state in nature, but is always found in combination with chemical radicals or other elements as fluoride compounds. When dissolved in water these compounds dissociate into ions. (An ion is an electrically charged atom). The fluoride ions in drinking water thus formed are responsible for caries reduction in teeth. There are only three basic (approved) compounds commonly used for fluoridating a drinking water supply in the United States: sodium fluoride, sodium silicofluoride, and hydrofluosilicic acid.

2.2.2. Chemical Sources

Fluoride can be found in a solid form in a fluoride-containing minerals such as fluorspar, apatite, and cryolite. Fluorspar is a mineral containing from 85 to 98 percent calcium fluoride (CaF_2). Fluorspar is found in most parts of the world with Kentucky and Illinois having the largest deposits in the United States. Apatite [$(Ca_{10}(PO_4CO_3)_6(FOH)_2$] is a deposit of a calcium compound of phosphate, fluorides, carbonates, and sulfates and is found in many southern States. Apatite is the main source of commercially used fluorides at the present time. It is the raw material for phosphateic fertilizers. Large deposits are found in Tennessee, Florida, and South Carolina, and minor deposits are found in North Carolina, Montana, Idaho, Utah, and Wyoming. Cryolite (Na_3 Al F_6) is a compound of aluminium, sodium, and fluoride. It is preferred in industry because of its low melting point. The chief deposits of commerical interests are in Greenland. Cryolite is not a major source of fluoride in this country.

Fluoride compounds are currently obtained from apatite which is mined and sent through a refining process. The fluoride ion is unchanged by this refining process. The ion is the same whether it is leached from the rock by nature or mined, extracted from the rock and refined to fortify and enrich otherwise deficient water. The source of the fluoride ion is immaterial to its absorption and use in the body. Fluoride is a natural component of water.

Due to the dissolving power of water and the movement of water in the hydrologic cycle, fluoride is found naturally in all waters. The municipal natural fluoride level in Massachusetts averages approximately .1 ppm. As water moves through the earth as groundwater it contacts fluoride-containing minerals and carries fluoride ions away from them. Because all water eventually goes to the ocean, sea water also contains fluorides (approximately 1.2 ppm). The concentration of fluoride found in fresh waters varies according to such factors as the depth at which the water is found and the quantity of fluoride bearing minerals in the area. Generally speaking, the deeper the groundwater, the greater the concentration of fluoride in the water. Some private rock wells (usually deeper than 500 feet) in Massachusetts have been found to contain natural fluoride levels up to 3.5 ppm.

2.2.3. Fluoride Compounds in General

Theoretically, any compound which forms fluoride ions in water solution can be used for adjusting the fluoride content of a water supply. However, there are several practical considerations involved in selecting compounds. First, the compound must have sufficient solubility to permit its use in routine water plant practice. Second, the cation to which the fluoride ion is attached must not have any undesirable characteristics. Third, the material should be relatively inexpensive, and readily available in grades of size and purity which are suitable for the intended use. Fluoride compounds, like chlorine, caustic soda, and many other chemicals used in water treatment can be constitute a safety harzard for the water plant operator unless proper precautions in handling are observed. It is essential that the operator be aware of the hazzard associated with each individual chemical prior to its use.

2.2.4 Chemical Availability

There has been some concern about the availability of sodium fluoride, sodium silicofluoride, and hydrofluosilicic acid from time to time. There has not been a shortage of these chemicals from the manufacturers. There have been shortages at some local distributors' levels. That type of problem is usually quickly eliminated. Occassionally a downturn in the chemical fertilizer industry may affect the production of hydrofluosilicic acid. Such temporary shortages can be best avoided by having a long term contract with a specific local vendor.

2.2.5 Sodium Fluoride

The first fluoride compound used in controlled fluoridation was sodium fluoride, selected not only on the basis of the above criteria, but also because its toxicity and physiological effects have been so thoroughly studied. In addition, sodium fluoride is the reference standard used in measuring fluoride concentration. Once fluoridation became an established practice, other compounds came into use, but sodium fluoride, because of its unique physical characteristics in addition to its other advantages in some situations, is still one of the most widely used chemicals.

Sodium fluoride is a white, odorless material (looks like white sugar) available either as a powder or in the form of crystals of various sizes. Its formula weight is 42.00, specific gravity 2.79, and its solubility practically constant at 4.0 grams per 100 milliliters in water at temperatures generally encountered in water treatment practice (see Table 2-1 on page 2-6). The pH (hydrogen-ion concentration) of a sodium fluoride solution varies with the type and amount of impurities, but solutions prepared from the usual grades of sodium fluoride exhibit pH's near neutrality (approximately 7.6). It is available in purities ranging from 90 to over 98 percent, the impurities consisting of water, free acid or alkali, sodium silicofluoride, sulfates and iron, plus traces of other substances.

Powdered sodium fluoride is produced in different densities, the light grade weighing less than 65 pounds per cubic foot and the heavy grade weighing about 90 pounds per cubic foot. A typical seive and analysis of powdered sodium fluoride shows 99 percent through 200 mesh and 97 percent through 325 mesh. Crystalline sodium fluoride is produced in six various ranges, usually designated roughly as coarse, fine and extra-fine, but some manufacturers can furnish many specific mesh sizes. The crystalline type is preferred when manual handling is involved, since the absence of fine powder results in a minimum of dust. Dust constitutes the most frequently encountered hazard in handling sodium fluoride. A more thorough discussion of handling precautions is discussed in following sections.

Sodium fluoride has a number of industrial uses. One use in the past was a rodenticide. It is no longer used as such and the Environmental Protection Agency (EPA) does not have sodium fluoride on their list of registered rodenticides.

Sodium fluoride is also used in the manufacture of vitrified enamel and glasses; as a steel degasing agent; in electroplating; in welding fluxes; in heat treating salt compounds; in sterilizing equipment in breweries and distilleries; in paste and mucilage; as a wood preservative; and in the manufacture of coated paper.

Table 2-1

SOLUBILITY OF FLUORIDE CHEMICALS

Chemical	Temperature (°C)	Solubility (g per 100ml of H_2O)
1. Sodium Fluoride*	0.0	4.00
	15.5	4.03
	20.0	4.05
	25.0	4.10
	100.0	5.00
2. Sodium Silicofluoride	0.0	0.44
	25.0	0.76
	37.8	0.98
	65.6	1.52
	100.0	2.45
3. Hydrofluosilicic Acid		Infinite at all temperature

*In the field the solubility may be quickly determined using a hand held refractometer, and the solubilities are usually found to be closer to (3.0 to 3.8)% or (3.0 to 3.8)g per 100 ml of H_2O(distilled).

2.2.6 Hydrofluosilicic Acid

Hydrofluosilicic acid (pronounced Hy-dro-FLEW-oh-suh-lys-ik), also known as hexafluosilicic or "silly" acid or silicofluoric acid, is a 20 to 35 percent aqueous fluosilicic solution of H_2SiF_6 with a formula weight of 144.08. It is a colorless (when pure), transparent, fuming, corrosive liquid having pungent odor and an irritating action on the skin. Solutions of 20 to 35 percent hydrofluosilicic acid exhibit a low pH (1.2), and at a concentration of 1 ppm in potable water there can be a slight depression of the pH of poorly buffered waters. It must be handled with great care because of the low pH and the fact that it will cause a "delayed burn" on skin tussue. Hydrofluosilicic acid (23 percent) will freeze at approximately 4° F or -15.5°C.

Hydrofluosilicic acid is manufactured by two different processes, resulting in products having differing characteristics. The largest production of the acid is a by-product of phosphate fertilizer manufacture. Phosphate rock is ground up and treated with sulfuric acid, forming a gas by-product. This gas is reacted with water, forming hydrofluosilicic acid. This type of acid is relatively impure and seldom exceeds 30 percent strength. Acid prepared from phosphate rock contains colloidal silica in carying amounts, and while this is of little consequence when the acid is used as received, dilution results in the formation of a visible precipitate of the silica. Some supplier of hydrofluosilicic acid sell a "fortified" acid, which has had a small amount of hydrofluoric acid added to it to prevent the formation of the precipitate. Acid prepared from hydrofluoric acid and silica does not normally form a precipitate when it is diluted.

Hydrofluoric acid is an extremely corrosive material. Its presence in hydrofluosilicic acid, whether from intentional addition, i.e., "fortified" acid or from normal production processes, which yield hydrofluoric acid and silicon tetrafluoride as impurities in the hydrofluosilicic acid, demands careful handling.

Since hydrofluosilicic acid contains a high proportion of water, shipping large quantities can be quite expensive. Larger users can purchase the acid directly from the manufacturers in bulk (tank car or truck) lots, but smaller users must obtain the acid from distributors who usually pack it in drums or polyethylene carboys. The price varies due to the variable characteristics of the acid as it commes from fertilizer plants. Rather than attempt to adjust the acid strength to some uniform figure, producers sell the acid as it comes, and the price is adjusted to compensate for acid strength above or below the quoted figure. It is recommended that purchasers of hydrofluosilicic acid specify that all bids be in the form of dollars per ton on a 100% basis. That way the user will pay for the actual strength received on a pro rata basis. Note that the "23 percent basis" type of pricing applies only to bulk quantities. It is the usual practice for the supplier to furnish assay reports of the acid strength of each lot.

For example, assume the bulk price bid is $550 per ton on a 100% basis. The vendor says the hydrofluosilicic acid is 25% pure. Your price would be $550 X 25% = $137.50 per ton. Since one ton = 2,000 pounds, the price per pound is $137.50/2,000 or 6.875 cents per pound.

Attempts to dilute the acid are subject to errors in measuring both the acid and the diluting water. It is much better to use the acid undiluted as it comes from the containers in which it is shipped. If the acid is too concentrated for the solution feeder to handle, then weaker solutions of other, less expensive compounds are generally indicated - for instance, saturated solutions of sodium fluoride. If the acid must be diluted, care should be taken to avoid the formation of a precipitate of silica, which will appear despite the quality (hardness) of the water for dilution.

Like all other fluoride compounds, hydrofluosilicic acid has a number of industrial uses, one of which is in the manufacturing of hydrofluosilicic acid, and thus in an indirect way, other fluoride compounds. Other uses include the sterilizing of equipment; in the brewery and bottling industries; electroplating; tanning of animal hides; etching of glass; refinement of lead; removal of moles; hardening of cement; and the preservation of wood.

As with all other mineral acids, hydrofluosilicic acid should be handled with care to prevent injury to operators and damage to equipment from acid splatter or fumes. A more thorough discussion of handling precautions is discussed in following sections.

2.2.7 Sodium Silicofluoride

Hydrofluosilicic acid can readily be converted into various salts, and one of these, sodium silicofluoride, is widely used as a chemical for water fluoridation. As with most silicofluorides, it is generally obtained as a by-product in the making of phosphorus fertilizers. Phosphate rock is ground up and treated with sulfuric acid forming a gas by-product. This gas is reacted with water forming hydrofluosilicic acid. When neutralized with sodium carbonate, sodium silicofluoride will precipitate out. Undoubtedly, the principal reason for this popularity is one of economics, for sodium silicofluoride is one of the cheapest compounds currently in use. The conversion of hydrofluosilicic acid, essentially a low-cost by-product which contains too much water to permit economical shipping, to a dry material containing a high percentage of available fluoride results in a compound having most of the advantages of the acid with few of its disadvantages. One it was shown that silicofluorides form fluoride ions in a water solution as readily as do simple fluoride compounds, and that there is no difference in physiological effects, the silicofluorides (and hydrofluosilicic acid) were rapidly accepted for water fluoridation, and in some cases have displaced the use of sodium fluoride, except in saturators.

Sodium silicofluoride is a white, odorless crystalline powder (looks like white flour). Its molecular weight is 188.06 and its specific gravity is 2.679. Its solubility varies from 0.44 grams per 100 milliliters of water at 0 degrees centigrade to 2.45 grams per 100 milliliters at 100 degrees C (see Table 2-1 on page 2-6). The pH's of solutions are definitely on the acid side, saturated solutions usually exhibiting pH's between 3.0 and 4.0. Sodium silicofluoride is available in purities of 98 percent or better, the principal impurities being water, chlorides, and silica.

Sodium silicofluoride is sold in two commercial forms - regular and fluffy. The former has a density of about 85 pounds per cubic foot while the latter has a density of about 65 pounds per cubic foot. A typical seive analysis of the regular grade shows more than 99 percent through a 200-mesh sieve and more than 10 percent through a 325-mesh sieve.

Sodium silicofluoride has been used in the past as a rodenticide, but like sodium fluoride, it no longer is used in this way. The U.S. Environmental Protection Agency does not list it as a registered rodenticide. Other industrial uses include: laundry scouring agent (neutralizing industrial caustic soaps); the manufacture of opal glass; and moth proofing woolens.

As in the case of sodium fluoride, the principal hazard associated with handling sodium silicofluoride is dust. Precautions for dealing with this material are discussed in later sections.

2.2.8 Other Fluoride Compounds

Ammonium silicofluoride, magnesium silicofluoride, potassium fluoride, hydrofluoric acid, and calcium fluoride (fluorspar) are being or have been used for water fluoridation. Each has particular properties which make the material desirable in a specific application, but also each had undesirable characteristics. None of these compounds have widespread application, or is approved by Massachusetts.

Ammonium silicofluoride had the peculiar advantage of supplying all or parts of the amonium ion necessary for the production of chloramine, when this form of disinfectant is preferred to chlorine in a particular situation. It has the disadvantage of hindering disinfection if there are short contact times. Also, it is more expensive to buy than sodium silicofluoride.

Magnesium silicofluoride and potassium fluoride have the advantage of extremely high solubility, of particular importance in such applications as school fluoridation, when infrequent refills of solution containers are desired. In addition, potassium fluoride is quite compatible with potassium hypochlorite, so a mixture of the two solutions can be used for simultaneous fluoridation and chlorination. The advantages are that these compounds cannot be fed in dry form. Also, they are both more expensive than sodium silicofluoride, especially potassium fluoride. Magnesium silicofluoride is widely used in Europe as a concrete curing compound and thus is mass produced. But, it is still more expensive than sodium silicofluoride.

Calcium fluoride (fluospar) is the cheapest of the compounds ever used for fluoridation, but it is also the least soluble. It has been successfully fed by first dissolving it in alum solution, and then utilizing the resultant solution to supply both the alum needed for coagulation and the fluoride ion. Some attempts have been made to feed fluorspar directly in the form of ultra-fine powder, on the premise that the powder would eventually dissolve or at least remain in suspension, until consumed. These attempts have not been very successful.

In South America many rural cities, especially in Brazil, are fluoridated using calcium fluoride since it is readily available domestically. One method is to place the chemical in a contact filter bed under a condition of non pressure flow at a water filtration plant. These methods have been reported successfully by the Pan American Health Organization (PAHO).

Hydrofluoric acid (not hydrofluosilicic acid), although low in cost, presents to much of a safety and corrosion hazard to be acceptable for water fluoridation, although it has been used in a specially designed installation.

A number of other fluoride compounds have been suggested for use in water fluoridation, among them ammonium and sodium bifluoride. These latter materials have the advantages of solubility and cost, but their potential corrosiveness has hindered acceptance.

Table 2-2 on page 2-10 gives the comparison between the three most commonly used fluoride chemicals and the other fluoride chemicals.

2.2.9 Operator Safety

While potable water fluoride levels at the recommended concentration of 1.0 ppm have been exhaustively studied and firmly established as safe beyond question, the fluoride levels to which the water plant operator can be exposed are potentially much higher. To prevent overexposure, the best safety measure is proper handling of

Table 2-2
COMPARISON OF FLUORIDATION CHEMICALS

Type	Approved Fluoride Chemicals			Other Fluoride Chemicals			
	Sodium silicofluoride (Na_2SiF_6)	Sodium fluoride (NaF)	Hydrofluosilicic acid (H_2SiF_6)	Calcium fluoride (CaF2)	Magnesium silicofluoride ($MgSiF_6 6H_2O$)	Ammonium silicofluoride ($(NH_4)_2SiF_6$)	Potassium fluoride ($KF\ 2H_2O$)
Form	Powder	Powder or Crystal	Liquid	Powder	Crystal	Crystal	Crystal
Molecular weight	188.05	42.00	144.08	78.08	274.48	178.14	94.13
Commercial purity %	98-99	90-98	22-30	85-98	98	98	98
Weight lb/cu.ft.	55-72	65-90	10.5 lb/gal	101	72	81	58
Lb. required per mg for 1.0 ppm fluoride at indicated purity (assuming no natural fluoride present)	14.0 (98%)	18.8 (98%)	35.2 (30%) 42.0 (25%) 45.7 (23%)	17.6 (96%)	20.5 (98%)	13.3 (98%)	42.1 (98%)
Solubility g/100ml H_2O at 25 deg. C	0.76	4.1	Infinite	0.00016	64.8 (17deg C)	18.5 (17 deg C)	100
pH of saturated solution	3.5	7.6	1.2	6.7	1.0	3.5	7.0

fluoride chemicals. Proper handling implies adequate knowledge of the material, the practice of correct procedure, and the use of indicated safety equipment.

There are times, however, that the operator may be overexposed to the fluoride chemicals, especially to dusts. These overexposures, whether they occur in water or in air, are called toxic exposures. there are two kinds or levels of toxic exposures, chronic toxic effects and acute toxic effects. There must be a clear distinction made between chronic toxic exposure to large doses of fluoride spread over a number of years and acute toxic exposure, which results from a single massive dose.

2.2.9.1 Chronic Toxic Exposure

The body's assimilation capacity for fluoride is limited. Storage begins at about 1.5 milligrams (mg) per day. It is estimated that low poisoning may start at 0.2 to 0.35 mg/day/kilogram of body weight (for 175 lbs that equals 15.9 to 27.8 mg).

The only toxic effect of low levels of fluoride (2 to 8 times that of the optimum level) is mottled enamel on the teeth. At higher levels of fluoride intake, osteosclerosis, calcification of ligaments and tendons, and/or vertebrae consolidation can occur. With chronic toxic exposure, there may be a general lack of appetite, slight nausea, some shortness of breath, constipation, pain in the region of the liver, and anemia.

Perhaps the greatest chance for overexposure to fluoride chemicals comes from the inhalation of dust generated when the feeder hoppers are being filled. During the filling operation, the operator should wear an effective NIOSH approved respirator, an apron, and rubber gloves. The respirator should have a rubber face-to-mask seal, with replaceable cartridges. Cartridges are available for either dust or acid vapor application. The maximum allowable concentration of fluoride dust in the area should be 0.2 to 0.3 milligrams/m^3 of air.

2.2.9.2 Acute Toxic Exposure

Acute fluoride poisoning may result from ingestion, inhalation or bodily contact with concentrated fluoride compounds. Not a lot is known about acute fluoride poisoning caused by ingestion or inhalation because it is a very rare occurrence. Accidental ingestion is quite unlikely, but might occur through contamination of food or drink either by mistaking the compound for sugar or salt or through carelessness by allowing areas where food is consumed to become grossly contaminated by dust or spillage.

The symptoms of acute poisoning by inhalation of dust or vapor include sharp biting pains in the nose followed by nasal discharge or nosebleed, and perhaps coughing or respiratory distress. Acid spill or splash may cause a tingling or burning sensation of the skin, or if the eyes are involved, severe eye irritation.

Ingested toxic dosages generally cause vomiting, stomach cramps, and diarrhea. If the poisoning involves ingestion of large amounts of fluorides, the vomitus may be white (or colored if the fluoride contains dye), and the victim may experience weakness, disturbed color vision, thirst, and have difficulty in speaking. Ingestion of 4 to 5 grams (per 175 pounds bodyweight) may be fatal.

2.2.9.3 First Aid for Acute Toxic Exposure

Once fluoride poisoning is established, first aid treatment should be started while waiting for medical help. The recommended first aid for ingested toxic fluoride dosages is:

1. Move the person away from any contact with fluoride and keep him warm.
2. Give the person 3 tablespoons full of table salt in a glass of warm water.
3. If the person is conscious, induce vomiting by rubbing back of the throat with a spoon or your finger; or use Ipecac.
4. Give the person a glass of milk.
5. Repeat the salt and vomiting several times
6. Take the person to the hospital as soon as possible.

For nosebleed:

1. Move the victim from the exposed area.
2. Keep the victim quiet.
3. Place the victim in a sitting position, leaning forward if possible; if that is not possible, place the victim in reclining position with the head and shoulders raised.
4. Apply pressure directly by pressing the bleeding nostril toward the midline.
5. Apply cold compresses to the victim's nose and face.
6. If bleeding cannot be controlled by the preceding measures, insert a small, clean pad of gauze (not absorbent cotton) into one or both nostrils and apply pressure externally with your thumb and index finger. A free end of the pad must extend outside the nostril so that the pad can be removed later.
7. If bleeding continues, obtain medical assistance.

For acid splash:

1. Wash away the chemical with large amounts of water as quickly as possible. Remove the victim's clothing from the areas involved and continue washing for at least five minutes.
2. Where skin damage has occurred, cover the burn with a dressing bandage and seek medical attention.
3. If the eye is involved, immediately begin to wash the eye, eyelid, and face. Hold the eyelid open and wash the eye for at least five minutes.
4. After a thorough washing, cover the eye with a clean, dry protective dressing and bandage in place, then transport the victim to a doctor.
5. All instances of eye injury require medical attention. Even seemingly minor eye injuries can leave the eye vulnerable to infections which can lead to blindness.

2.2.10 Chemical Storage and Handling

There are a number of criteria governing the selection of a storage site for fluoridating chemicals. The dry chemicals must be kept dry, they must be convenient to the hopper in which they will be loaded, they should preferably be isolated from other water treatment chemicals to preclude accidental intermixing; the storage area must be clean and well ventilated, and should be equipped with running water and a floor drain for ease in cleaning up spills. Hydrofluosilicic

acid presents particular problems in storage, for the vapors are corrosive and will even etch glass. Containers must be kept tightly closed, or vented to the outdoors. Large quantities of acid can be stored in underground or enclosed tanks equipped with outside vents.

Dry fluoride compounds, i.e., sodium fluoride and sodium silicofluoride, have a tendency to compact or cake when exposed to moisture or when bags are stacked too high. Similar conditions can result from long periods of storage, so an oversupply of chemicals should be avoided. Store dry fluorides on pallets, in stacks preferably not more than six bags high. If fiber drums are used, keep the tops closed to prevent moisture absorption. Do not allow unauthorized personnel, especially small children, in areas where fluoride chemicals are fed or stored.

When fluoride sacks are handled carelessly, or if the bags are emptied too quickly, airborne fluoride dust levels may become dangerously high. Do not toss the bags. When opening the bags, cut an even slit across the top to avoid tearing the sides. Pour the contents of the bags gently into the feed hopper. Do not bellows the empty bag. Good ventilation is absolutely necessary in work areas, even if there is no visible dust production.

The disposal of empty fluoride containers has always been a problem. The temptation to re-use fiber drums is difficult to overcome, since the drums are convenient and sturdy. Paper bags are dusty and could cause a hazard if they are burned, and empty acid drums could contain enough acid to cause contamination. The best approach is to rinse all empty containers with plenty of water - even the paper bags are strong enough to withstand repeated rinses. After all traces of fluoride are removed, the bags should be disposed of in a proper manner. Please check with DEQE FOR THE CORRECT ADVICE. Even supposedly well-rinsed drums should never be used where traces of fluoride could present a hazard. If possible, the storage area should be kept locked and not used for any other purpose. In particular, workers should be warned against eating in a fluoride storage area.

Hydrofluosilicic acid requires special precautions. The 30 percent acid has a freezing point around 4 degrees F. Do not store hydrofluosilicic acid containers in the hot sun where they can build hydrostatic pressure or in open areas subject to winter freezing.

The fumes from the acid are highly corrosive, and will even etch glass. Any glass, such as, gage or clock faces may be covered with small pieces of clear plastic, such as, saran wrap. Store hydrofluosilicic acid in well ventilated areas, well away from switches, contacts, and control panels. Although the acid is available in the all-polyethylene drums, some suppliers continue to ship in lined steel drums which may suffer leakage problems. Wash down all spills immediately.

Always wear protective safety gear when handling fluoride chemicals, and, in particular, wear goggles when handling the acids, and respirators when handling dusty or fuming compounds.

2.3 Fluoridation Installation and Operation

2.3.1 Introduction

Fluoridation installation and operation must be considered as one and, as such, their various components cannot be chosen without considering their effect on each other. For instance; each of the characteristics of fluoride compounds described will have, to some extent, a direct bearing on the selection of the best feeder to use, its location, the point of fluoride application, and the type of auxiliary equipment.

The best installation is one that incorporates as many of these factors as possible:

1. Simple, accurate feeding equipment
2. Minimum chemical handling
3. Consistent with the above two factors, the lowest overall cost based on amortization of equipment and cost of chemical
4. Ease in collecting reliable records
5. Minimum maintenance of feeder, piping, and injector equipment

A thorough knowledge of the types of equipment available is a must in order to determine the best installation.

2.3.2 Methods of Feeding Fluorides

Fluoride must be fed into the water supply system in liquid form or as a solution. This is true if you have dry chemical feeders or if you have solution feeders.

Fluorides can be fed into a water supply in the following ways:

1. The amount of dry chemical compound (usually sodium silicofluoride) can be measured with a machine, then added to a mixing tank (solution tank) where it is thoroughly mixed and then delivered to the main flow of water.

2. A small metering pump (feeder) can be used to add solutions of hydrofluosilicic acid directly to the water supply system. This method can use the acid as delivered.

3. Saturated solutions of sodium fluoride in constant strengths of four percent can be produced in a saturator tank at almost any temperature of water encountered in the usual water plant. This saturated solution can be pumped with a small solution feeder directly into the main flow of water of a water supply system. The use of these devices eliminates the need for weighing sodium fluoride, measuring solution water volume, and stirring to insure dissolving.

2.3.3 Types of Feeders

Devices for feeding fluorides accurately have generally been adapted from those machines originally designed for feeding a variety of liquid or solid chemicals in water-treatment and industrial plants. In many cases, the equipment is the same.

Fluoride chemicals are added to a water supply either as liquids or solids. The solid form of fluorides must be dissolved into a solution before entering the

water supply system. Chemical feeders can therefore be broadly divided into two types: (1) solution feeders, which are essentially small pumps used to feed a carefully measured quantity of accurately prepared fluoride solution (hydrofluosilicic acid) during a specific time; and (2) dry feeders, which deliver a predetermined quantity of the solid material during a given time interval. Dry feeders are further subdivided by type, depending on the method of controlling the rate of delivery. Volumetric dry feeders deliver a measured volume of dry chemical within a given time interval; gravimetric feeders deliver a measured weight of chemical within a given period.

The choice of a feeder depends on the fluoride compound used and the amount to be fed. The rate of feed will depend on the desired fluoride content of the treated water, the amount of water to be treated passing a given point, and the fluoride content of the untreated water. In general, solution feeders are used for the smaller water supply systems and dry feeders for the larger systems. There is, of course, a wide area within which either type would be equally successful. Table 2-3 on page 2-16 lists the types of feeders and their capacities.

2.3.3.1 Solution Feeders

In general, a solution feeder is nothing more than a small pump, of which there are almost unlimited varieties. For feeding fluoride solutions, almost every type of feeder which has ever been used for feeding other water treatment chemicals can be used, with at most, only minor modification in construction details. There are three common types of solution feeders (all positive displacement types) now used for fluoridation: the diaphragm pump, the peristaltic pump, and the electronic pump.

If there is, indeed, any requirement for a fluoride solution feeder which distinguishes it from feeders for other purposes, it is the accuracy and constancy of delivery required. The optimum fluoride level has been prescribed between very narrow limits and thus requires that the fluoride be added in precise proportion to the quantity of water being treated. This requirement favors the so-called positive displacement pump or feeder, defined as a feeder which delivers a specific volume of liquid for each stroke of a piston or rotation of an impeller. Of course, very few feeders deliver replicate volumes under all conditions, for such factors as pressure and viscosity can affect the volume displaced by the driving member of the pump. However, by using fluoride solutions of fixed strength, by feeding against a fixed pressure, and by pumping usually into a constant flow of water, the positive displacement feeder has shown sufficient reliability.

For gravity feed, there are several types of solution feeders which operate on the paddle-wheel principle. A rotating wheel equipped with small buckets dips solution from a constant-head tank and discharges the solution into the water to be treated. Rate of feed can be varied by changing the size of the buckets or their number, by changing the rate of rotation of the wheel, or by varying the proportion of the bucket contents which are emptied.

Ordinarily, such solution feeding devices as centrifugal pumps, pot feeders, or head tank and orifice are not used for fluoridation because of their relative inaccuracy. However, in addition to the three common types of solution feeders mentioned above, there are several types of rotary pumps which qualify as positive-displacement feeders. These include gear, swinging-vane, sliding-vane, oscillating screw, eccentric and cam pumps, and various modifications of these pumps.

TABLE 2-3
USUAL RANGE OF FLUORIDE FEEDERS

Type of Feeder	Chemical Used	General Feed Rate Range
Gravimetric (dry feeder)	Na_2SiF_6	0.5 to 5,000 lbs. per hr
Volumetric (dry feeder)	Na_2SiF_6 NaF	0.1 to 5,000 lbs per hr
Piston or centrifugal pump (Solution feeder)	Solutions of H_2SiF_6 Solution of 4% NaF	18.4 to 5,000 gallons per day
Diaphragm Pump (Solution feeder)	Solutions of H_2SiF_6 Solution of 4% NaF or 1% Na_2SiF_6	9 to 2,500 gallons per day
Electronic Pump (Solution feeder)	Solutions of H_2SiF_6 Solution of 4% NaF	.15 to 96 gallons per day
Water Operated Pump (Solution feeder)	Solutions of H_2SiF_6 Solution of 4% NaF	15-60 gallons per day

TABLE 2-4
RECOMMENDED MAXIMUM WITHDRAWAL RATES FOR SODIUM FLUORIDE SATURATOR

Bed Depth	Water Temperature		
	60 degrees F	50 degrees F	40 degrees F
6"	3.17 gph	2.77 gph	2.38 gph
6-1/2"	3.57 gph	3.17 gph	2.77 gph
7"	3.96 gph	3.57 gph	3.17 gph
7-1/2"	4.36 gph	3.96 gph	3.57 gph
8"	4.76 gph	4.36 gph	3.96 gph
8-1/2"	5.15 gph	4.76 gph	4.36 gph
9"	5.55 gph	5.15 gph	4.76 gph
9-1/2"	5.94 gph	5.55 gph	5.15 gph
10"	6.34 gph	5.94 gph	5.55 gph

The criteria used in selecting a feeder are capacity, corrosion resistance, pressure capability, and of course, accuracy and durability. A point to consider is that most feeders perform most accurately near midrange of both stroke length and stroking frequency and should be selected accordingly. Most feeders come equipped with plastic heads and resilient check-valves, both of which are satisfactory for fluoride solutions unless the pressure is over approximately 150 psi. For higher pressures, corrosion-resistant alloys, such as 316 stainless steel or Carpenter 20 alloy, are required for feeder head construction. Always check with the pump manufacturer to assure wetted pump parts are compatible with fluoride solution to be used.

Since most solution feeders are adjustable both for stroke length, which determines the volume of liquid delivered per stroke, and stroke frequency, usually expressed in strokes-per-minute (SPM), both factors should be considered in selecting the size of feeder for a particular application.

Diaphragm Metering Pumps

For delivery against pressure (as is most always the case in a fluoridated water system), the positive displacement type pump is best and the type approved. There are many types of positive displacement pumps on the market but most share the following principle of operation.

Each pump head consists of a chamber with a suction port or opening at the bottom and a discharge port at the top. Each port has a check valve (also referred to as poppet or ball valve) to assure flow in the proper direction. One wall of the chamber is a pulsating diaphragm which alternately increases and decreases the chamber volume.

The diaphragm is driven by a variety of power forces created by a push rod, solenoid valve, oil reservoir or other device. There are two basic types of driving the diaphragm a mechanically activated type (least expensive) and hydraulically activated type (more expensive). See figure 2.1 on page 2-18 for a typical mechanically activated diaphragm type metering pump.

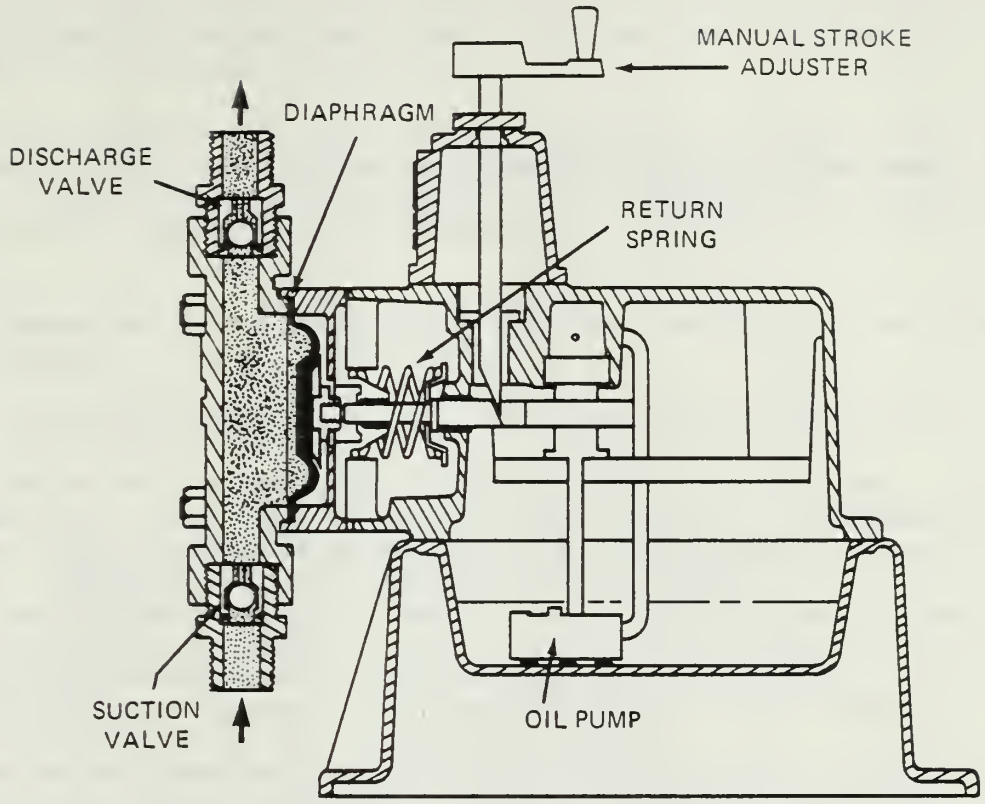
On the suction stroke, the diaphragm develops a vacuum in the chamber. This closes the discharge check valve, opens the suction check valve, and allows the fluoride solution into the chamber. At the end of the suction stroke, the diaphragm reverses direction and begins the discharge stroke. The diaphragm is pushed into the feeding chamber. As the volume of the chamber decreases, the suction valve closes, the discharge check valve opens, and the fluoride solution is forced out of the head into the discharge line.

At the end of the discharge stroke, the diaphragm reverses direction and begins another cycle of filling and emptying the feeding head. This process repeats itself quite rapidly and as often as once per second.

Feed rate is usually regulated by a combination of stroking rate (strokes per minute) and stroke length.

Stroking rate or speed may be adjusted manually on some pumps by changing a dial or pulleys on the motor. On other pumps there is only one fixed stroking rate, and there is no adjustment.

FIGURE 2-1
TYPICAL DIAPHRAGM SOLUTION FEEDER



NOTE: There are two types:
mechanically activated diaphragm pump
and
hydraulically activated diaphragm pump

Stroke length may be adjusted manually on the pumps by changing a dial in increments of usually 1% in a scale of (0-100)%. To increase the feed rate, one would adjust the stroke length higher and to decrease the stroke length, one would adjust the stroke length lower. On most pumps this may be accomplished with the pump operating.

Diaphragm pumps are ideally suited for pressures up to 200 psi (pounds per square inch). For pressures less than 5 psi they should not be used, and never against a vacuum, such as that obtained in the suction side of a water pump. A constant positive pressure on the discharge is a guarantee of their continued accuracy.

Diaphragm pumps can fail and may become airborne, resulting in suboptimum fluoride levels.

Some of the reasons causing a low or erratic pump output may include:

1. Very low stroke setting-should be above (10-20)% at all times.
2. Trapped air in pump head-to remove, pump to waste at a temporary higher output. Check suction line and seal ring on pump head for leaks. (Note: trapped air in discharge line has no effect.)
3. Air leak through valve seats-inspect (use magnifying glass), clean or replace, tighten securely.
4. Ruptured diaphragm-inspect for holes, replace if necessary.
5. Clogged injection nozzle - depressurize discharge line, inspect, clean and replace injection check valve if necessary.
6. Injection into excesive pressure - check discharge pressure against maximum pump rating. Pump should be rated at least 25 psi above. (Note: spring pressure in injection check valve should be considered as well as friction losses in the discharge line).
7. Belt slips - adjust belt tension if so equipped.
8. Fluoride solution not pumped - check to make sure footvalve is cleaned, in a vertical position, and in the fluoride solution container.
9. Pump not working - check fuses and if power is available. Some motors are equipped with overload protector, allowing motor to cool before starting.
10. Fluoride solution drips - check connections and tighten.
11. Clogged lines - check and clean suction and discharge lines to remove stoppage, also check anti-siphon and/or pressure release valves.
12. Pump suction line not sloped continuously upward toward pump - adjust suction line so it slopes gradually upward with no hills or loops.
13. Pump constantly airbound - remove and place near floor for flooded suction condition - only advise as a last resort with advise and permission of DPH.
14. Pump loses prime - check diameter of suction line against recommendation of pump manufacturer, should be as short as possible.
15. Delivery gradually changes - check stroke adjustment knob for creeping, replace worn parts as needed.

Water Operated Feeder

A water operated pump is a positive displacement pump that uses water pressure to pump a liquid (fluoride solution) into a water main. The pump is paced by a positive displacement water meter, so that at any feed rate setting, fluoride feed is always proportional to flow. An advantage is low cost and no electrical power is required; a disadvantage is the minimum capacity of 15 gallons per day.

During the spring powered suction stroke, pressure in a chamber behind the pumping diaphragm is at atmospheric. Main pressure partially closes a balancing water valve. (See figure 2-2 on page 2-21), Only a small flow of leakage through this valve goes to the balancing - water chamber. When the discharge stroke begins, the power - diaphragm yoke closes the open end of the pumping shaft. This traps the leakage and pressure begins to build up in the chamber. At this point, the valve quickly passes enough water to the chamber to equalize pressure in the pumping chamber. Pressure is maintained throughout the discharge stroke.

This is the "balanced-diaphragm" pumping method. It permits a relatively small pressure behind a power diaphragm to execute the discharge stroke against main pressures up to 125 psi.

Power for the discharge stroke is furnished by a continuous flow of main water up to 4 inches in diameter. Set by a flow controller, this water goes to a chamber behind a power diaghragm. A take off from the water-meter register shaft rotates a cam. The cam operates a small pilot valve. The water required to operate the pump at full capacity is approximately 2/3 of a gallon per minute.

When cam rotation closes the pilot valve, pressure builds up behind the power diaphragm. This pressure drives the power diaphragm, yoke, pump shaft and pumping diaphragm forward for the discharge stroke. At completion of the discharge stroke, cam action opens the pilot valve and relieves the pressure behind the power diaphragm. The spring returns the pump shaft for the suction stroke. Water from the balancing - water and power - water chambers drains to waste.

A mechanical stroke-stop limits movement of the power diaphragm and its yoke. Stroke-stop setting controls stroke length.

Water operated fluoride pumps are generally not used much in Massachusetts, but is some remote parts of the country they are quite common, especially in remote reservoirs.

Electronic Feeders

The electronic pump is a special case of a diaphragm pump. (see Figure 2-3 on page 2-22. Most diaphragm pumps used for fluoridation, as explained in the previous section, have a flexible diaphragm driven by a mechanical linkage. An electronic pump has a solenoid that is periodically energized to move the flexible diaphragm. It has solid state electronics, circuit breakers, and an anti-siphon valve. It can have eight manual or automatic controls and variable stroke and speed. The minimum output capacity is 0.15 gallons per day. The electronic pump is a relatively new pump, but is gaining rapidly in acceptance. It appears to be ideal for small fluoridated systems, especially ones using hydrofluosilicic acid. One advantage of an electronic type pump is the savings in electricity as the pump only draws power during the discharge stroke.

2.3.3.2 Calibration of Solution Feeders

Solution feed pumps are usually accompanied by a chart showing the number of milliliters per minute that the pump will actually remove from the solution container.

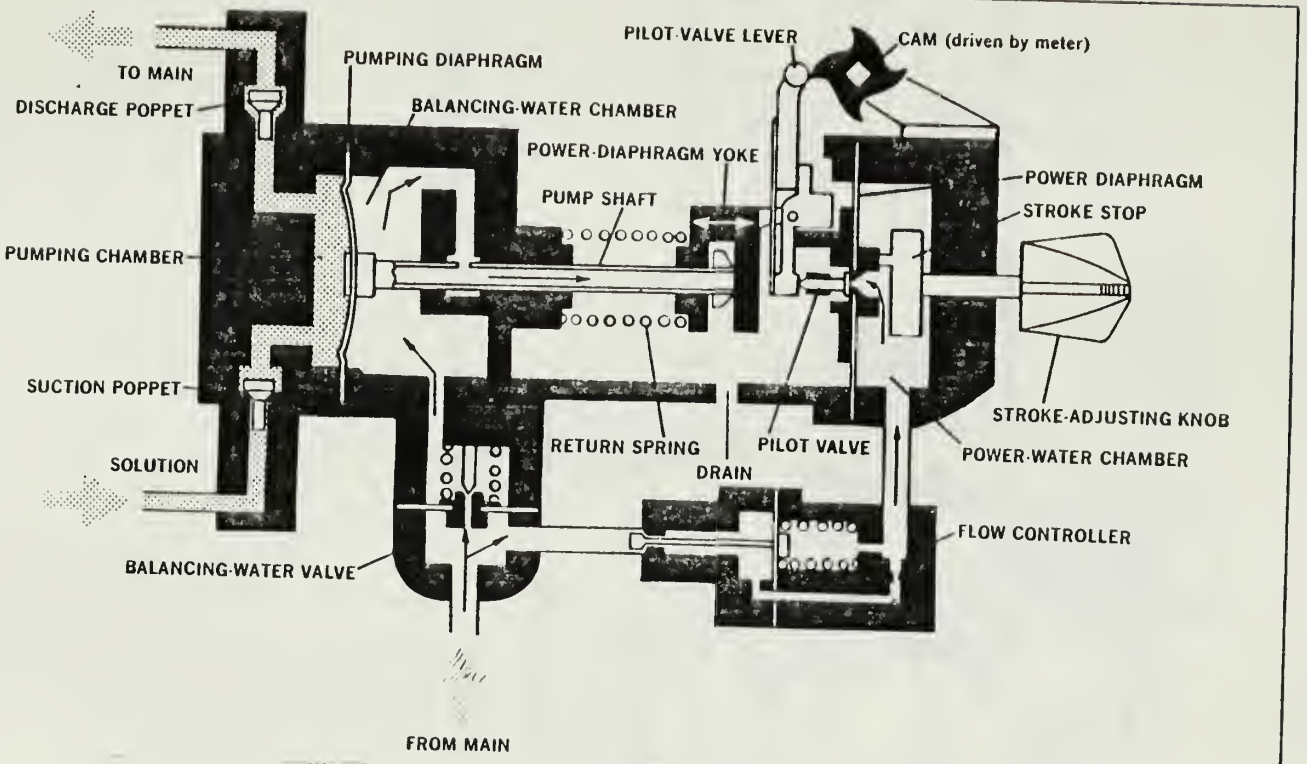
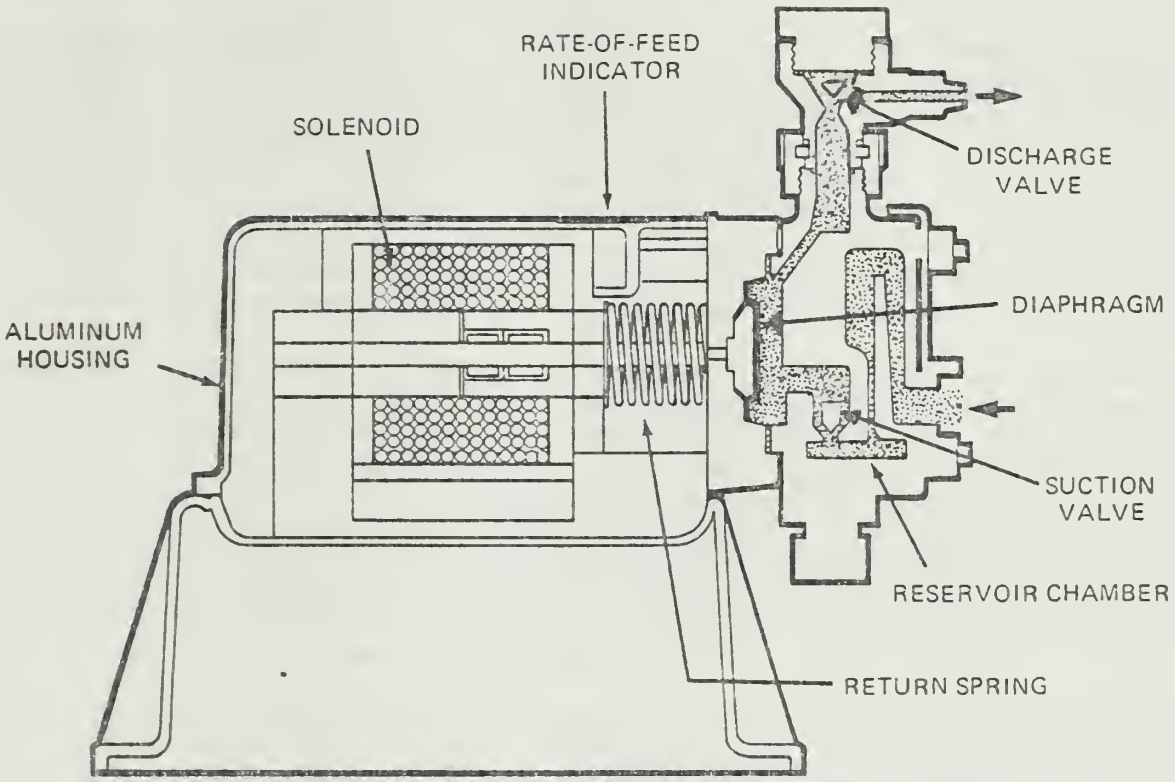


Figure 2-2
Typical Water Operated Pump

FIGURE 2-3
TYPICAL ELECTRONIC FEEDER



If this chart is not available, then one must be made up by adjusting the feeder to various settings and measuring the amount of solutions pumped during the measured time intervals. This should also be done periodically to verify the delivery rate of a solution feeder or to make adjustment when the feed rate is too high or too low.

Simply measuring the output from the discharge outlet of the feeder is unsatisfactory, since eventhe output of so-called positive displacement pumps varies with pressure. One acceptable way is to measure a volume of the liquid being pumped, preferably in a graduated cylinder (without losing prime of spilling any solution). Feed for a timed interval, withdraw the suction tube and note the volume of solution remaining. The difference will represent the volume fed during the measured interval. By adjusting the feeder to various scale settings, a calibration chart or curve can be developed which will be representative of the pumping conditions and the chemical pumped at the time.

Another way to calibrate a solution feeder that is superior to the above method, especially with acid solutions, is to equip the solution tank with a permanent wall mounted calibrated sight glass or calibration chamber. By closing the valve between the sight glass and tank (the sight glass is outside the tank), and opening the valve between the sight glass and suction line, while the feeder is operating normally, solution will be withdrawn from the sight glass only, and the volume over a timed interval can be calculated. This system has the advantage of freedom of interruption of fluoride addition as well as avoiding direct contact with the chemical being fed. After the measurement, opening the valves will be all that is necessary to resume normal feed.

The rate of feed in milliliters per minute can be calculated from the feed rate in pounds or gallons per day. Once the feed rate has been calculated in pounds per day, it is a simple matter to determine the solution pump feed rate in ml/min. Please see the fluoridation calculation section for the step-by-step calculations.

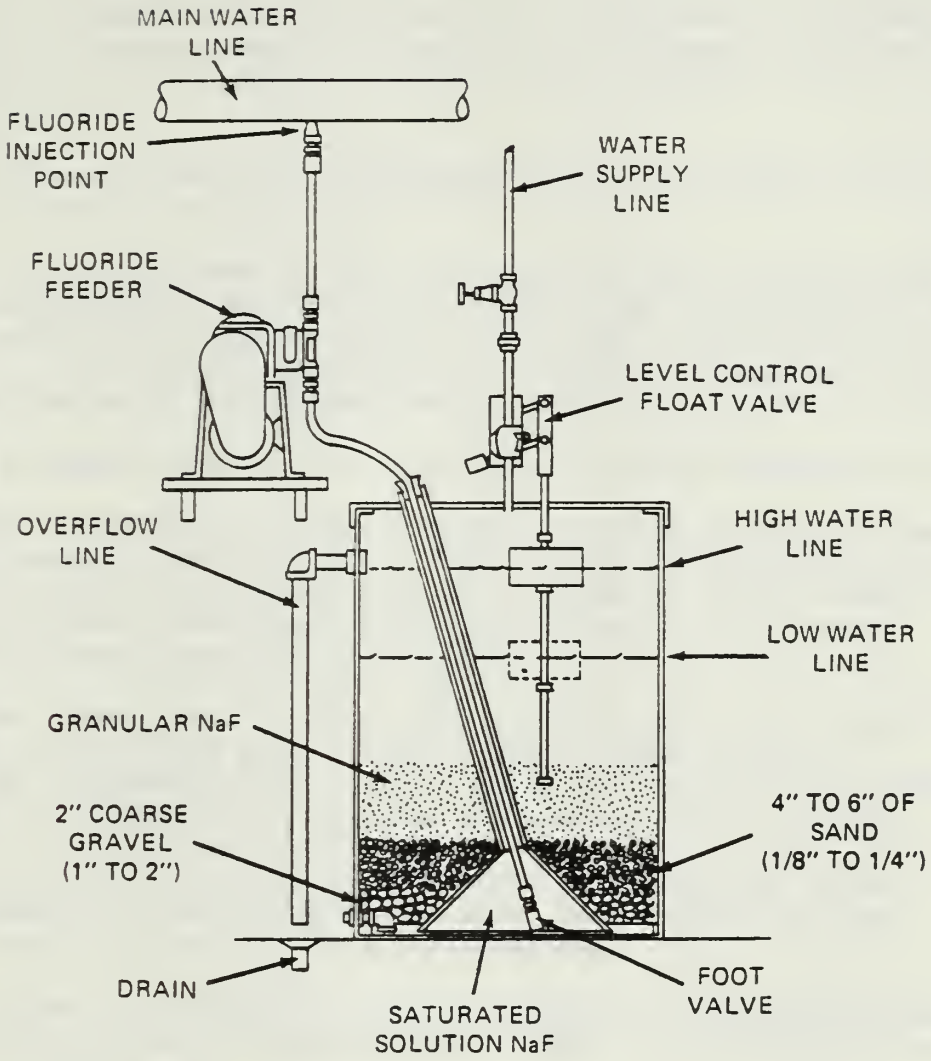
2.3.3.3 Saturators

The saturator is a special application of a solution feeder. A small pump delivers a saturated solution of sodium fluoride into the water supply system instead of a solution of hydrofluosilicic acid. The principle of a saturator is that a saturated solution will result if water is allowed to trickle through a bed containing a large amount of sodium fluoride. Although saturated solutions of sodium fluoride can be manually prepared, generally the easiest and best way is an automatic feed device. There are two kinds of saturators, the upflow saturator and the downflow saturator.

Downflow Saturator (Not approved for new installations in Massachusetts because of increased maintenance problems).

In the downflow saturator, the solid sodium fluoride is held in a plastic drum or barrel and is isolated from the prepared solution by a plastic cone or a pipe manifold. A filtration barrier is provided by layers of sand and gravel to prevent particles of undissolved sodium fluoride from infiltrating the solution area under the cone or within the pipe manifold. The feeder pump draws the solution from within the cone or manifold at the bottom of the plastic drum. (See Figure 2-4 on page 2-24).

FIGURE 2-4
TYPICAL DOWNFLOW SATURATOR



Some local waterworks operators have used turkey grit in place of the sand.

When a downflow-type saturator is in operation, water is admitted at the top of the saturator tank (where there is an air gap to avoid the possibility of a cross-connection) and the level is regulated with a float-operated controller. The water then trickles down through the bed of sodium fluoride, the solution is clarified in the sand and gravel filter bed, and ends up as a clear, saturated solution at the bottom of the tank where it is withdrawn by the feeder. The only operator attention required is to see that an adequate quantity of sodium fluoride is kept in the saturator and that the saturator is kept in a reasonably clean condition.

Table 2-4, page 2-16, gives the recommended maximum withdrawal rate for a downflow saturator in gallons per hour (gph).

Table 2-5, page 2-26, gives the maximum water flow rate in gallons per minute (gpm), which can be fluoridated to a level of 1.0 ppm F for each respective bed depth and water temperature, assuming there is less than 0.1 ppm natural fluoride content in the water. Higher flow rates can be fluoridated if there is higher natural fluoride content or if the desired level is less than 1.0 ppm F.

To prepare a downflow saturator for use, the following steps should be taken:

A. 1. With the manifold in place, carefully place by hand a 2-3" layer of coarse, clean gravel (1-2" size) in the saturator tank around the manifold or cone and over the manifold or over the lower edge of the cone. Then place another 2-3" layer of finer gravel (1/2-1" size) over the coarse gravel.

2. Place a 6-9" layer of clean, sharp, filter sand over the gravel. (Do not use beach sand, "clayey" sand, or ordinary soil.) Level the sand surface. (A 12" bed of 1/8" to 1/4" filter gravel can be substituted for the sand and coarse gravel layers.)

B. Add 200 lbs. of coarse crystalline sodium fluoride. (Do not use powdered NaF or fine crystal). Add water to keep down the dust and to assist in leveling the fluoride surface.

C. Check to see if the float has room to operate. If necessary, make a depression in the fluoride surface to provide clearance for the float and float rod.

D. If you have not already done so, connect a cold-water supply line to the water intake of the saturator. The line should contain a small water meter (5/8") for use in calculating the feed rate, and there should be a shut-off valve between the meter and the saturator.

E. Turn on the water supply and adjust the float position if necessary. The low-water level should be no less than 2" above the fluoride surface, and the high-water level should be just below the over flow outlet.

F. Insert the feeder suction line into the pipe leading to the inner cone or manifold as the case may be. Adjust length of suction line so that the foot-valve and strainer are 2-3" above the bottom of the saturator tank. The saturator is now ready for use.

TABLE 2-5
RECOMMENDED MAXIMUM FEED RATES FOR A SODIUM FLUORIDE DOWNFLOW SATURATOR

Bed Depth	Water Temperature		
	60 degrees F	50 degrees F	40 degrees F
6"	950 gpm	830 gpm	710 gpm
6-1/2"	1,065 gpm	950 gpm	830 gpm
7"	1,190 gpm	1,065 gpm	950 gpm
7-1/2"	1,300 gpm	1,190 gpm	1,065 gpm
8"	1,425 gpm	1,300 gpm	1,190 gpm
8-1/2"	1,550 gpm	1,425 gpm	1,300 gpm
9"	1,660 gpm	1,550 gpm	1,425 gpm
9-1/2"	1,780 gpm	1,660 gpm	1,550 gpm
10"	1,900 gpm	1,780 gpm	1,660 gpm

TABLE 2-6
DETENTION TIME OF SODIUM SILICOFLUORIDE IN SOLUTION TANKS

Feed Rate lbs/hr	Min. Water Flow Rate Required for Solution	Solution Tank Size				
		5 gallons	10 gallons	25 gallons	50 gallons	100 gallons
1	1 gpm	5 min	10 min	25 min	50 min	100 min
2	2		5	12.5	25	50
3	3			8.3	16.7	33.3
4	4			6.2	12.5	25
5	5			5	10	20
6	6				8.3	16.7
7	7				7.1	14.3
8	8				6.2	12.5
9	9				5.5	11.1
10	10				5	10
20	20					5

G. By looking through the translucent wall of the saturator tank, you should be able to distinguish the layers of fluoride, sand, and gravel. When the thickness of the fluoride layer decreases to 6", add another 100 lbs. of fluoride. It would be wise to add the fluoride when the water level is at its lowest level, or if necessary, to shut off the water temporarily until there is enough room for the fluoride without causing water to come out of the overflow opening.

H. If the saturator is being used at a rate that is more than 1500 gpm of water being treated (see Table 2-5 on page 2-26) fluoride should be added daily in sufficient amount to keep the fluoride layer at a thickness of at least 10".

I. Before more fluoride is added to the saturator, the surface of the fluoride layer in the saturator should be scraped free of accumulated dirt, insoluble material, or the slimy film of fine particles that sometime forms. Such routine maintenance permits better percolation of water through the fluoride layer and extends the length of time between clean-outs, and helps prevent air binding.

J. At regular intervals, usually on an annual basis, but depending on the severity of use, the saturator will have to be cleaned out. A typical schedule calls for a clean-out every three months when the quantity of water being treated is in excess of 1500 gpm and the accumulation of dirt in the saturator is moderate. The clean-out procedure is as follows:

1. Continue using the saturator until the level of sodium fluoride is as low as practicable. Shut off the water supply to permit the level of water to drop down to the fluoride layer. This step minimizes the wastage of chemical and decreases the amount of material which will have to be removed.

2. Scoop out the remaining sodium fluoride, sand, and gravel. If the sand and gravel are to be reused, place them in separate buckets. If fresh sand and gravel are available, dispose of the old material as required by the State agency involved with solid waste.

3. Remove the inner cone or manifold assambly and clean the inside of the saturator tank. Replace the cleaned cone or manifold.

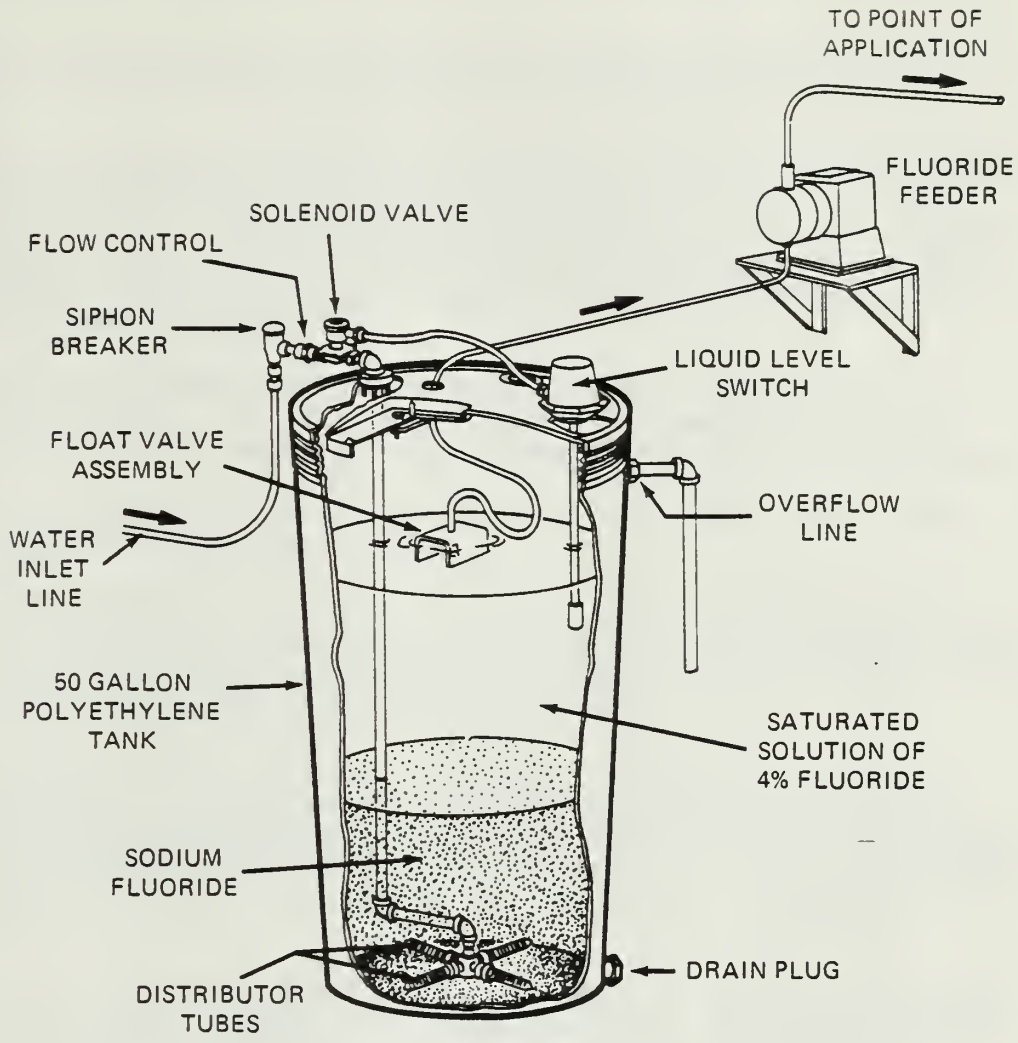
4. If the old sand and gravel are to be reused, wash them repeatedly with water until all traces of fluoride and dirt are removed. Then reconstruct the filter bed of sand and gravel as before with either the cleaned or fresh material.

5. Add sodium fluoride as before and return the saturator to normal operation. (Don't forget to turn on the water supply again.)

Upflow Saturator (Recommended highly over downflow type saturator)

In an upflow saturator, undissolved sodium fluoride forms its own bed below which water is forced upward under pressure (see Figure 2-5 on page 2-29). No barrier is used since the water comes up through the bed of sodium fluoride and the specific gravity of the solid material keeps it from rising into the area of the clear solution above. A spider type water distributor located at the bottom of the tank contains hundreds of very small slits. Water, forced under pressure through these slits flows upward through the sodium fluoride bed at a controlled rate to assure the desired 4 percent solution. The feeder pump intake line floats or is fixed on top of the solution in order to avoid withdrawal of undissolved sodium fluoride. The water pressure

FIGURE 2-5
TYPICAL UPFLOW SATURATOR



NOTE: Massachusetts Department of Environmental Quality Engineering requires all new upflow saturators to have an approved type of reduced pressure backflow preventer on the make-up water line. This applies to all upflow saturators installed after January 1, 1982.

requirements are 20 psi minimum to 125 psi maximum, and the flow is regulated at 4 gpm. Since introduction of water to the bottom of the saturator constitutes a definite cross-connection, use a reduced pressure backflow preventer. Such device must be an approved DEQE model. These are required on all new installation effective January 1, 1982.

To prepare an upflow saturator for use, the following steps should be taken:

A. With the distributor tubes in place, and the floating suction device removed, add 200 to 300 pounds of soidum fluoride directly to the tank. Any type of sodium fluoride can be used, from coarse crystal to fine crystal, but fine crystal will dissolve better than coarse materials. Powder can be used, but is not as desirable as a crystal form of sodium fluoride.

B. Connect the solenoid water valve to an electric outlet and turn on the water supply. The water level should be slightly below the over-flow; if it is not, the liquid level switch should be adjusted.

C. Replace the intake float and connect it to the feeder intake line. The saturator is now ready to use.

D. By looking through the translucent wall of the saturator tank, you should be able to see the level of undissolved sodium fluoride, a drop light suspended behind the saturator will help. Whenever the level is low enough, add another 100 pounds of fluoride.

E. The water distributor slits are supposed to be essentially self-cleaning, and the accumulation of insolubles and precipitates does not constitute as serious a problem as it does in a down-flow saturator. However, periodic cleaning is still required. Frequency of cleaning is dictated by the severity of use and the rate of accumulation of debris.

F. Because of the thicker bed of sodium fluoride attainable in an upflow saturator, higher withdrawal rates are possible. With 300 pounds of sodium fluoride in the saturator tank, more than 15 gallons per hour of saturated solution can be fed - a rate sufficient to treat about 5,000 gallons per minute of water to a fluoride level of 1.0 ppm.

G. Precautions regarding hard water apply similarly to both types of saturators.

H. The method for calculating the amount of fluoride feed is the same for both types of saturators. The fixed water inlet rate of 4 gpm should register satisfactorily on 5/8" meter.

2.3.3.4. Dry Feeders

When a large water supply system is to be fluoridated with sodium silicofluoride or sodium fluoride then a dry chemical feeder must be used. Dry chemical feeders deliver a predetermined quantity of fluoride chemical in a given time interval. There are two types of dry feeders which have

different methods of controlling the rate of delivery, volumetric and gravimetric. The volumetric dry feeder delivers a measured volume of dry fluoride chemical per unit of time and the gravimetric dry feeders deliver a measured weight of chemical per unit of time.

Volumetric Feeders

Volumetric feeders are essentially a combination of a driving mechanism, a means for delivering a constant volume of dry compound, a hopper for holding the compound, and a chamber for dissolving the compound before discharge into the water supply.

The chemical-delivery mechanism is a convenient means for distinguishing one type of volumetric feeder from another. Almost evey manufacturer has a different design for feeding chemicals volumetrically. These might be classified according to several types: rotating disk, oscillating pan, vibratory pan, reciprocating screw, rotating roller, star wheel, and combinations of these types.

Brief descriptions of the various types are given here merely to indicate the broad principles of operation. More complete details are readily obtainable from the manufacturers.

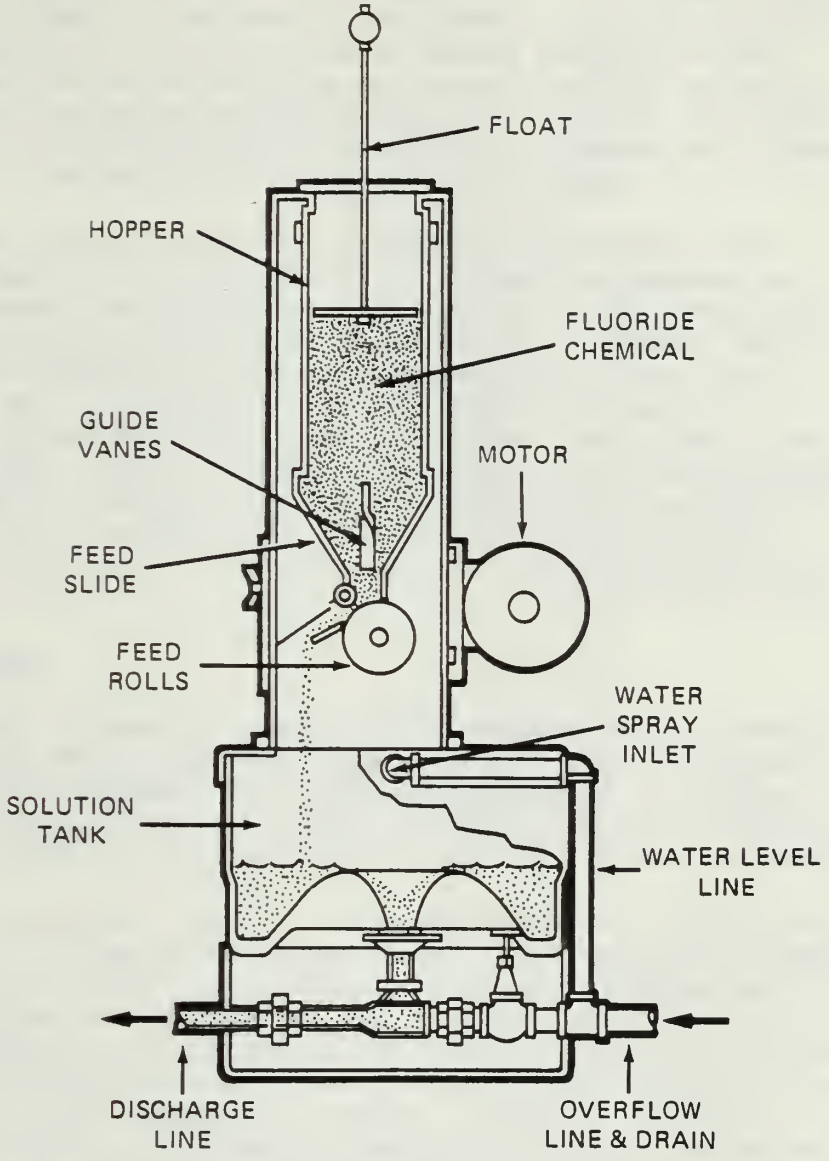
The roll-type feeder with a feed slide adjustment was, in the past, one of the most widely used feeders, particularly in the smaller plants. (See Figure 2-6 on page 2-32.) Today, they are not as popular as the screw-type feeders. In the roll-type feeder, the fluoride chemical is placed in the hopper through a top opening. From the hopper it flows by gravity to the feed rolls. A float in the hopper lid indicates the level of material in the hopper. The sides of the hopper and the built-in guide vanes flex with an oscillating motion to provide constant agitation. This prevents arching, caking, or packing and assures uniform feeding to the feed rollers.

Stainless steel feed rollers driven in opposite directions form the material into a smooth ribbon of uniform thickness. Feed rate is adjusted externally on a graduated feed slide by varying the width of this ribbon. If the feeder is equipped with a variable speed drive, it has no feed slide. The feed rate is then adjusted by changing input rpm to the three-speed gearbox. Material leaves the rolls at a uniform rate, falls into a solution tank, and is discharged to the main water system.

The roll-type volumetric feeder feeds powdery or granular dry, free-flowing materials at rates from 0.08 cubic feet per hour to 30 cfh.

The oscillating-pan (oscillating hopper) type of feeder consists essentially of a flat, narrow pan or trough into which the fluoride compound falls from a hopper above. Either the pan or the lower part of the hopper slowly oscillates along the axis of the pan, forcing the removal along the two open edges of the pan of a portion of the chemical in the pan. Delivery rates are controlled by both the speed of oscillation and the length of the oscillary stroke or the thickness of the chemical on the pan. The various sizes depend on the delivery ranges - from 2 ounces per hour up to 50 pounds per hour of sodium fluoride.

FIGURE 2-6
VOLUMETRIC FEEDER, ROLL-TYPE



The vibratory-pan feeder is a device for discharging a volume of chemical from a pan, chute, or trough made to vibrate electrically. A magnet is energized by means of a pulsating current (either ordinary alternating current or rectified, pulsating direct current). The trough is mounted on springs and connected directly to the magnet. The action of the tray is downward and backward on the power stroke, and upward and forward on the next stroke through the action of the springs. The material on the tray moves forward slightly on each stroke and appears to flow like water because of the high stroking frequence (3,600 strokes per minute on 60-cycle current). The rate of delivery is controlled by a rheostat, which determines the voltage and consequently, the degree of movement of the trough.

The most popular type of volumetric feeder is the rotating screw feeder. (See Figure 2-7 on page 2-34.) The fluoride chemical is placed in the hopper through the top. It settles to the bottom by gravity. An arrangement with vibrating plates in the hopper walls provides constant agitation. Agitation extends to the feed screw (hopper bottom) and is designed to prevent arching and packing. It helps maintain uniform delivery to the feed screw. An eccentric on the feed screw shaft drives a rocker arm connected to vibrating plates in the hopper walls. The feed screw gives single-ended delivery of fluoride to the solution tank at a uniform rate via the discharge line. There are a range of feed rates between 0.03 and 50 cubic feet per hour.

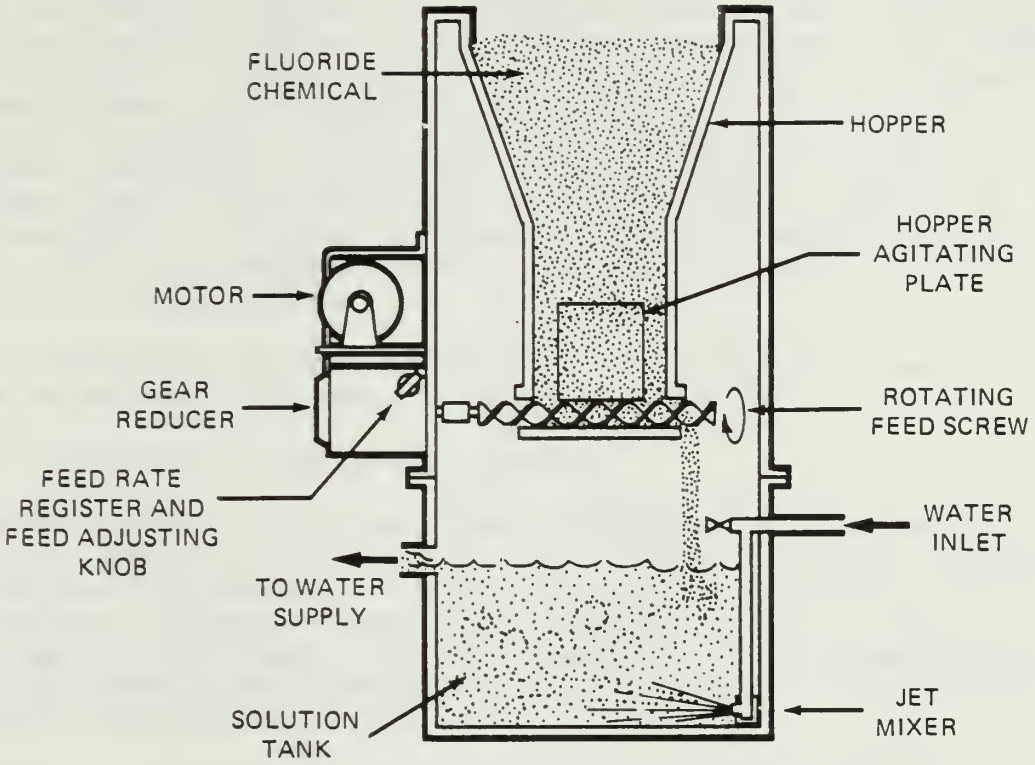
Gravimetric Feeders

Gravimetric feeders discharge chemicals at a constant weight rather than at a constant volume during a given period of time. Gravimetric feeders are readily adaptable for recording quantities of chemical feed and for automatic control. Another advantage is that a constant weight will be fed even if the bulk density of the compound has changed.

The weight of the chemical must be continuously measured because control of these feeders is based entirely on weight. Such control is accomplished in two basic ways. In one, the container (storage bin or hopper) is continuously weighed and the rate of loss in weight of the material in the hopper is automatically maintained by prior selection of the rate of feed. The discharge is so regulated that the material left in the hopper follows a linear reduction in weight. In the other type, a section of a moving belt carrying the chemical is weighed and deviations from a desired pre-set rate causes the amount of chemical to be increased or decreased.

The first type (loss in weight) consists of a hopper suspended from a scale system, an electrical-mechanical system for moving the poise on the scale beam, a mechanical means for moving the compound from the hopper in an amount depending on the position of the scale beam, and a dissolving chamber. The lead screw drive (a synchronous motor) moves the poise along the beam at a pre-set rate of speed. If more material is momentarily fed than indicated by the position of the poise, then the beam will lower. This action moves the control wedge (near the oscillator) downward, permitting a decrease in the amplitude of the stroke driving the star wheel or vibrating feeder mechanism. Less

FIGURE 2-7
VOLUMETRIC FEEDER, SCREW-TYPE



material will then be delivered until the weight of compound remaining in the hopper is again balanced by the weight of the scale beam. The error in feeding in this type of feeder is generally less than 1 percent. The minimum delivery is 10 pounds per hour with a range of feed in the order of 100 to 1, while some models can deliver more than 2 tons per hour.

The other type of gravimetric feeder is one in which a section of a loaded, moving belt is continuously weighed (see Figure 2-8 on page 2-36). The weight of the belt is balanced by a scale beam. The position of the beam controls delivery of the compound onto the belt. Any deviation from this weight on the belt causes the vertical gate to go up or down thus causing more or less material to fall onto the belt. Vibrations imparted to a diaphragm on the hopper are generated by an eccentric and transmitted through a wedge which varies the amplitude of the vibrations, depending on the position of the scale beam. Accuracy in these feeders is in the order of 99 percent or more. Range of feed is as much as 100 to 1, and adjustments are readily made merely by moving the poise on the scale beam.

Almost any volumetric feeder (including the vibratory types) can be adapted to perform as a gravimetric feeder.

2.3.3.5 Calibration of Dry Chemical Feeders

The rate of feed of a dry chemical feeder can be varied by adjusting the controls according to a scale. The numbers on this scale have no particular units and cannot be converted to ppm or mg/l until a calibration chart or curve has been prepared. A separate calibration chart is required for each machine and for each chemical fed by the machine. If it is possible to operate your water plant at more than one rate, then you must also have different calibration charts for each plant rate.

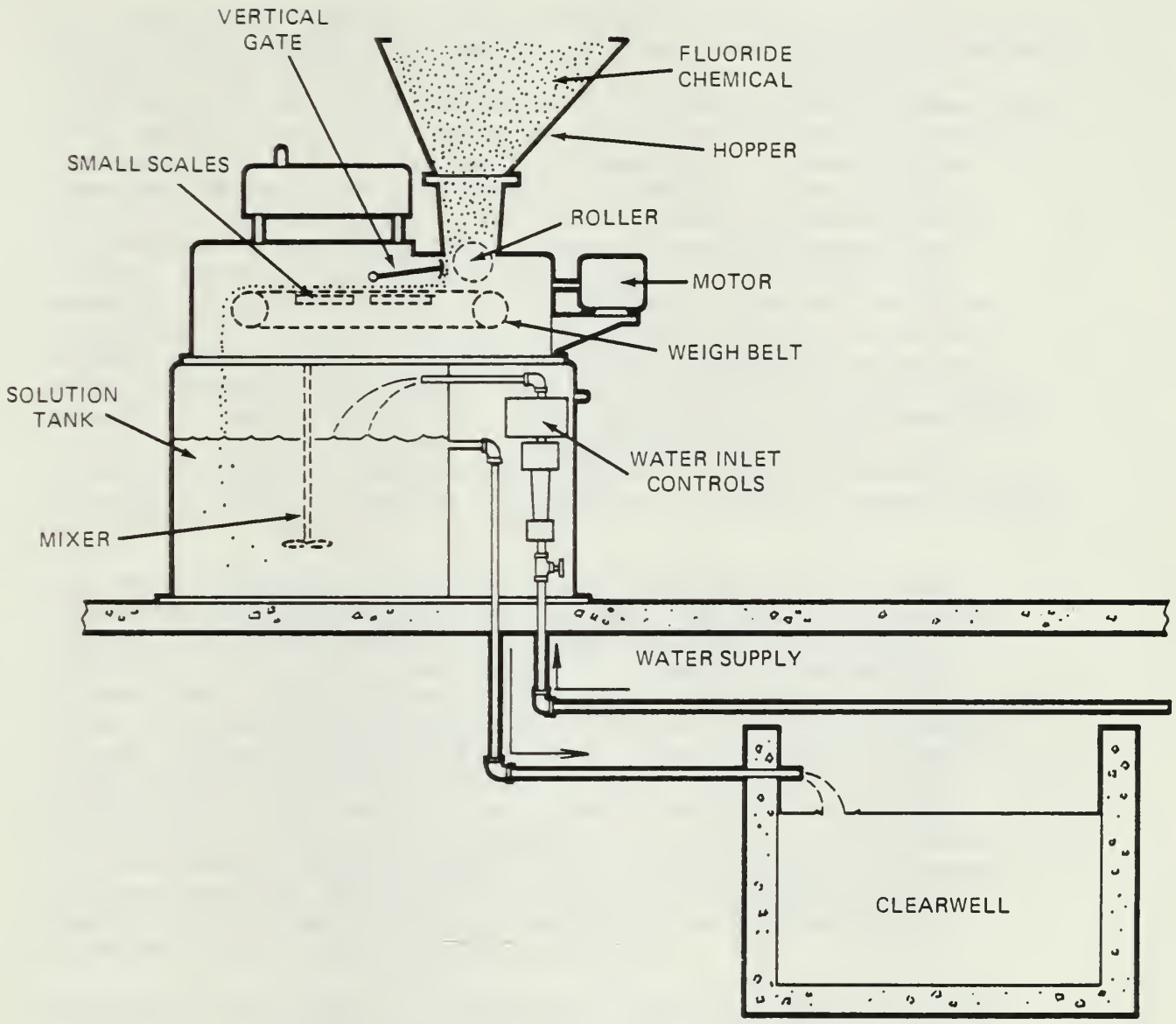
To calibrate a dry feeder, fill the hopper to the normal depth with the chemical to be fed. Be sure the chemical is dry, free-flowing, and contains no lumps.

Set the machine adjustment on a low number, certainly lower than you would ever operate. Allow the machine to run for a few minutes so that it is feeding uniformly. Then with a pan or cardboard box (which has been weighed empty), catch the total discharge of chemical from the feeder for several minutes (say five minutes). Weigh the chemical on the laboratory balance (in grams) and make a record on a chart.

Repeat the same operation for other scale settings on the machine, usually four or five different settings. Be sure to cover the full range at which the feeder will be operated.

Post the calibration curves near the machines (be sure to label each curve for the right machine) so that they can be used without mistakes or loss of time.

FIGURE 2-8
GRAVIMETRIC FEEDER, BELT TYPE



The feed rate of a given machine, when operating at a given setting, will vary with such things as machine wear, humidity, variation in texture of chemical being fed, etc.; therefore, a calibration curve should not be used over an extended period without verifying the accuracy of the curve.

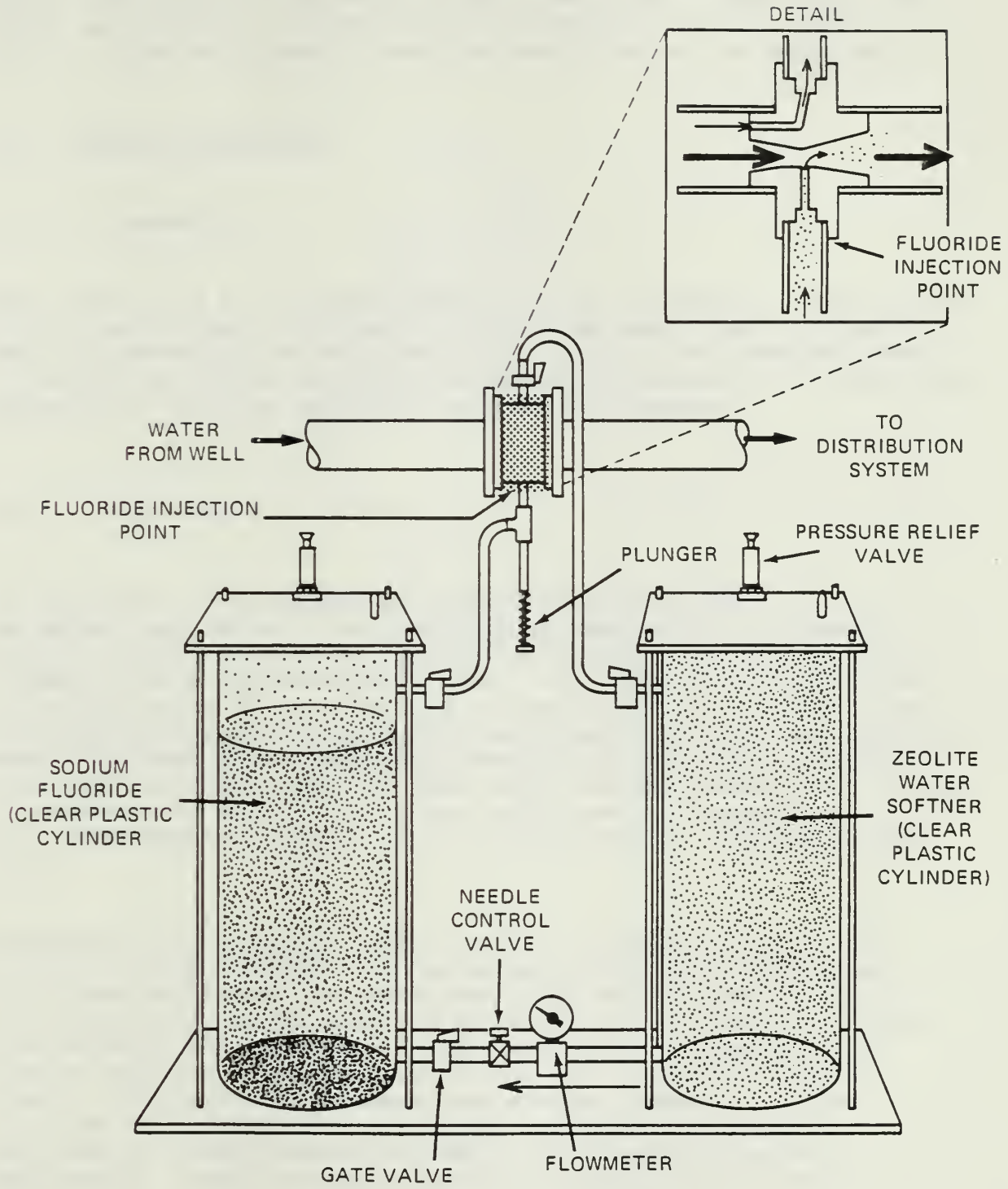
2.3.3.6 Venturi Fluoridators

The Indian Health Service (IHS), a branch of the United States Public Health Service (USPHS), has operated a formal community water fluoridation program in many Indian communities for many years. Because of the rural nature of the populations served, the limited size of communities, water systems, and utility authority staffs, and the unavailabity of convenient repair personnel and parts suppliers, it became evident to them that operation and maintenance problems were preventing the delivery of optimal levels of fluoride in numerous instances; thus, Mr. John Leo of the IHS designed a Venturi-type of fluoride feed system. The new fluoridation system design using the Venturi is actually a take-off from the aircraft industry, where Mr. Leo gained experience in uses of the Venturi. Figure 2-9 on page 2-38 depicts a typical Venturi; there is no possibility of accidental overdosing or slugs of fluoride being induced into the distribution system when the main water pump is inoperative. Also, since the unit is non-electrical, it can be installed anywhere, including water supplies that have a spring as a source. The fact that the tank containing fluoride is made of a clear plexiglass enables the operator to visually inspect the level of chemical at any time and replenish it.

The Venturi fluoridator operates in the following way. The water flows from the main line into the top small line and then flows into a softener unit containing zeolite. After the water is softened, it exits from the softening tank through a flowmeter (floating ball variety) and a screw micrometer-type needle valve to the sodium fluoride tank. This needle valve acts as the fine tuner for the fluoridation system. Without this valve, each water system would need a venturi valve manufactured specifically for the flow rate for a particular water system. Water entering the cylinder containing the sodium fluoride becomes saturated. A saturated solution of sodium fluoride is established as long as enough fluoride crystals exist to maintain the concentration. The saturated fluoridation solution is then siphoned off through the line by the venturi jet located at the fluoride injection point into the main line.

Where the incoming water to the system is not hard (less than 50 ppm hardness), the softening unit could be eliminated from the system, as encrustation will be minimal. But, even with a softening system, a gradual buildup of salts can occur in the small orifice in the throat of the Venturi. To remove this buildup, an encrustation removal valve that operates similarly to a paper punch is included in the system and is located at the Venturi throat orifice (fluoride injection point). The actuating, simple, pushing-in action will clear encrustation away from the PVC Venturi orifice without the operator having to take the system apart or disassembling any part of it. Frequency of the feed-rate, and velocities; however, in most systems, once every 3-4 weeks should be adequate.

FIGURE 2-9
VENTURI FLUORIDATOR



Practically speaking, the venturi system may have a range of applicability from a single family dwelling up through a small metropolitan area. The major variable is the size of the fluoride reservoir. Theoretically, the larger the reservoir, the less fluoride increments need to be added as refills. There are, however, practical limitations to this application.

2.3.4 Auxiliary Equipment

2.3.4.1 Introduction

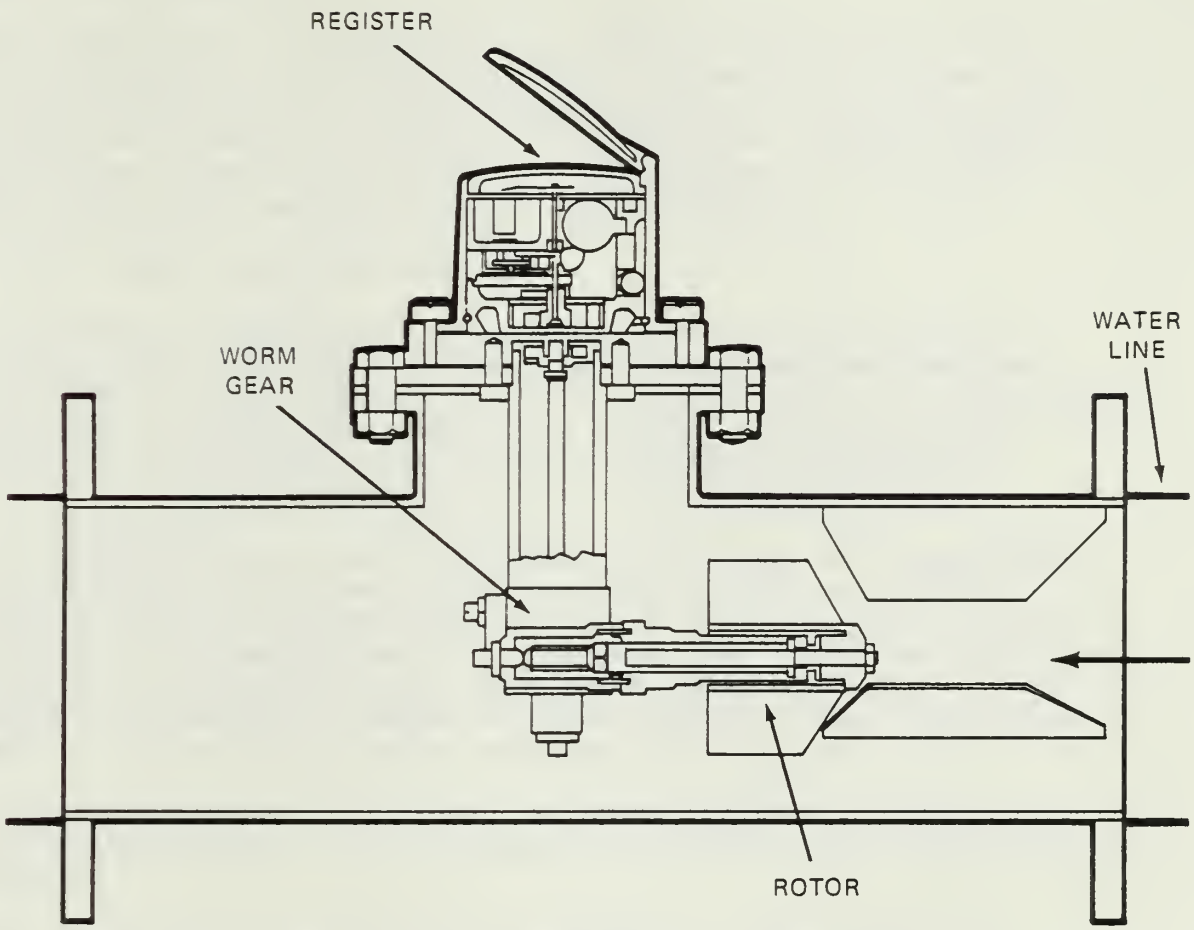
Most systems that do fluoridate require auxiliary equipment. The following sections will explain each type of auxiliary equipment that is commonly used in fluoridation and where each item belogs in a fluoridation system. As the size and complexity of the fluoridation system grows, the number and complexity of auxiliary equipment required also increases.

2.3.4.2 Water Meters

The water meter, often absent in the smallest water plants, is one of the primary requisites for accurate fluoride feeding. A water meter measures the flow of water in a water line (volume). Usually, the unit of measurement is gallons or cubic feet. (See Figure 2-10 on page 2-40.) This type of meter in the water line at home is read once a month and the difference between two months figures is the amount of water used that month. But note, with a water meter there is no way to know the rate of flow or when the water was used. Many times the term "water meter" is used to describe water meters, flow meters, pacing meters, compound meters, etc. While this is incorrect, it is a common practice in the waterworks field.

A water meter is installed in the water line where the flow or volume of water is to be measured. This is called an "in-line" installation. In a simple well system, the water meter would be installed in-line on the discharge side of the pump. If the water supply system is unmetered, calculations of fluoride feed rate will have to be by guesswork, and even the selection of an appropriate feeder will have to be somewhat "chancy." The type of water meter used depends largely on the flow rate; disc or piston meters are used for low flows, and compound, propeller, or magnetic meters are used for the higher flow rates. Unfortunately, meters are usually sold by pipe size, not flow rate, so all too often the water meter is grossly oversized for the flow rate

FIGURE 2-10
TYPICAL PROPELLER WATER METER



through it. Since most meters are least accurate at the low end of their measurement range, the result is that many times water flow is not accurately measured. The remedy is to select a meter no larger than necessary to handle the maximum flow rates expected, even if the pipe and meter sizes don't match. In some cases, this may involve the use of pipe reducers to adapt the water main to the meter, a practice which is acceptable, provided pressure loss as a result of this arrangement is not excessive.

Other applications for water meters, besides the main supply meters discussed above, are on supply lines for solution make-up water. In the case of the sodium fluoride saturator, a meter is a necessity, for without one it would be difficult to calculate the fluoride feed rate. Since water usage rate in a saturator installation is minimal, the meter must be the smallest available (usually 5/8").

2.3.4.3 Flow Meters (Pacing Meters)

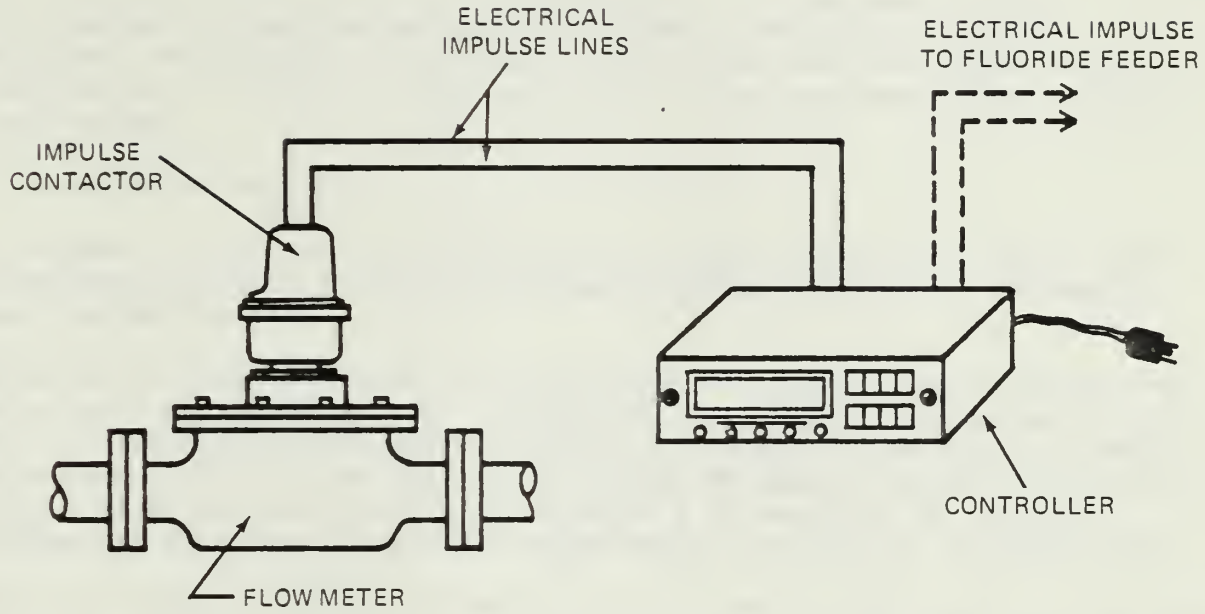
A flow meter, in contrast to an ordinary water meter, measures rate of flow rather than volume of flow. While those used for measuring flow rates in large pipelines operate on various differential-pressure principles, the flow meters applicable to small flows are usually based on the lifting of a spherical or cylindrical "float" by the hydraulic action of a flowing fluid in a vertical tube.

In a water plant where the water output is variable, as in cases where more than one pump is used, a flow-meter on the main can serve two purposes: It will indicate the flow rates on which the fluoride feeder or feeders must operate, and if so designed, will provide an electrical, pneumatic, or hydraulic signal which can be used to adjust the feeder output to correspond to changes in water flow rate. This type of flow meter is called a pacing meter (see Figure 2-11 on page 2-42).

A flow meter has units of gallons per minute, gallons per hour, cubic feet per minute, etc. It is installed in-line where the flow is to be measured.

When there is only one well pump, operating at a fixed rate, the fluoride feeder can be tied electrically to the pump operation and the fluoride feed will remain constant. When two well pumps are used, two separate feeders can be used, or one feeder can be adjusted manually each time the second pump cuts in or out. For more than two pumps, or where there is no fixed delivery rate, manual adjustment becomes very impractical. Thus, a pacing meter is required to adjust the feeder whenever there is a change in the flow rate of water. A pacing meter is just a flow meter with electrical contacts (usually). As the flow of water goes through the meter, the top of the meter rotates. When the top of the meter rotates, electrical contact is made as the reed switch passes over the electrical points. The faster the water flow, the faster the top will rotate and the more frequent the electrical connections are made. As electrical contact is made, an electrical impulse is sent to a relay where the short burst of electrical current is changed to a longer electrical signal. This signal (electrical current) can go directly to the fluoride feeder or to a timer connected to the fluoride feeder. Either way the fluoride feeder is turned on for a short period of time. In summary, as the flow of water increases

FIGURE 2-11
TYPICAL PACING METER APPLICATION



the flow meter topspins faster sending more signals through the relay to the fluoride feeder which in turn delivers more fluoride into the water system. Thus, the feeder is adjusted to the rate of flow in the water system.

A pacing meter, of course, is a complicated piece of equipment and should only be used in fluoridation when it is absolutely necessary. It should never be used when the flow rate is constant as when a community has a single well for their sole water supply source.

The flow meter or pacing meter must be selected on the basis of pipe size, nature of fluid (water) and particularly, the range of flows expected. For the greatest accuracy, the range of the flow meter should coincide with the range of flows which will be encountered in the particular installation.

2.3.4.3A Pacing Methods

In addition to a pacing meter, there are two other types of pacing systems (open loop) available to yield consistant fluoride levels over a change in water production rates.

The first and most expensive and complicated is a fluoride motor driven pump driven by a 4-20 milli-amp mA SCR signal from a transmitter on the venturi. The fluoride motor is DC (direct current) not AC type. The DC motor usually has a base speed of 1,750 RPM, and is capable of running between 0-1,750 RPM, hence a variable speed motor. The speed of a DC motor can be varied by varying the armature voltage while maintaining a voltage on the motor field.

The motor spins at a speed proportional to the rate of water flow in the main being fluoridated. As the motor spins faster the fluoride pump pumps more volume and vice-versa. With a 4 mA signal no water is flowing and the fluoride motor is stopped at ORPM; with a 20mA signal the water is flowing at the maximum rated capacity through the main venturi and the fluoride motor is spinning at 1,750 RPM. With a 12 mA signal the fluoride motor is at half speed and the water production rate is at the mid point capacity of the venturi.

This pacing system is very complicated electronically and requires maintenance beyond the limits of the average operator. Its advantage is that the fluoride is not slug fed, and mixing will be accomplished in the main very quickly.

The other type of pacing system available uses the time-pulse metering principle. It is rather inexpensive and simple compared to the variable speed pacing system.

The time-pulse (or impulse duration) is widely used. The control is based on a cam contracting mechanism which has a range of (12-60) seconds per cycle 60 seconds is common. The cam assembly is part of the transmitter that receives a high and low pressure signal from a venturi.

The repeating cam turns and generates an electrical signal which will pace a fluoride feeder pump either by turning the fluoride pump off and on repeatedly or by repeatedly controlling a solenoid valve on the pump suction line.

If the fluoride pump turns off and on repeatedly a special 3 phase motor and across the line magnetic motor starter may be needed. The off-on of the fluoride pump means slug feeding which could mean a mixing distance of over a 100 feet in the main depending on the time the fluoride pump is in the off or "no pump" condition. A typical example at 400 GPM could give a fluoride pump running for 40 seconds, off for 20 seconds, on for 40 seconds, off for 20 seconds and so on. Later on with the operator turning off a high lift pump and a total production dropping to 200 GPM, a fluoride pump would then be running on for 20 seconds, off for 40 seconds, on for 20 seconds, off for 40 seconds and so on.

When the repeating cam controls the electrical solenoid valve on the pump suction line, the solenoid valve allows the pump to pump water in the open position and a fluoride solution in the closed position. This is accomplished by a tee. The pump is running continuously all the time. The solenoid valve alternates between pumping fluoride and water. The same example can be used here. At 400 GPM, a fluoride pump would pump fluoride for 40 seconds (solenoid closed) and just water for 20 seconds (solenoid open), then fluoride for 40 seconds, and just water for 20 seconds and so on. Later on with the operator turning off a high lift pump and a total production rate dropping to 200 GPM, a fluoride pump would then pump fluoride for 20 seconds (solenoid valve closed), and just water for 40 seconds (solenoid valve open) , fluoride for 20 seconds, just water for 40 seconds, and so on. This pacing system is often called the feed flush method and it can be readily repaired by the typical operator fairly easily. The usual repair is either fixing a sticking check valve on the suction line tee or replacing a burned out 110 volt solenoid valve.

The closed-loop pacing control system is rather complex and will not be discussed in detail in this manual.

2.3.4.4. Softeners

When a fluoridation system involving the use of sodium fluoride solution (primarily a saturator) is being considered, it should be remembered that, while sodium fluoride is quite soluble, the fluorides of calcium and magnesium are not. Thus, the fluoride ions in solution will combine with calcium and magnesium ions in the make-up water and form a precipitate which can clog the feeder, the injection port, the feeder suction line, the saturator bed, etc. For this reason, water used for sodium fluoride dissolution should be softened whenever the hardness exceeds 50 to 75 ppm, or even less if the amount of labor involved in clearing stoppages or removing scale is objectionable. Remember - the entire water supply need not be softened - only the water used for solution preparation.

Two types of softening treatment are available - ion exchange and the use of polyphosphates (calgon, micormet, etc.) The ion exchange method of softening removes excess hardness. The polyphosphate sequester (keep in solution) the hardness elements. Since the volume of water to be softened is usually quite small, a household type of zeolite water softener is usually adequate. This type of softenener operates on the ion-exchange principle, and can be installed directly in the pipeline used for solution make-up. When softening capacity is exhausted, the zeolite (or synthetic resin) can be regenerated with brine made from common salt. Discharge to a floor drain is required which should terminate at least 100 feet away from a well to prevent contamination.

The primary use for water softeners, especially the zeolite softeners, is for the make-up water for a sodium fluoride saturator. Whenever a saturator is being considered to fluoridate a water supply system, a softener should also be discussed.

Failure to use a softener when it is required will result in the saturator clogging up quickly and eventually the metering pump becoming airbound on a saturator.

2.3.4.5 Day Tanks

A day tank is just what the name implies - a tank which holds a day's supply of a particular water treatment chemical. It is a convenient and often necessary means for isolating the supply of fluoride solution which will be fed during one day or shift at the water plant. Sometimes these tanks are called 30-hour tanks.

The day tank is a necessity when feeding large amounts of hydrofluosilicic acid, particularly if the acid is received and stored in a large tank. In order to provide a record of the weight of acid fed, a small quantity of the acid is pumped or siphoned into a small tank mounted on a platform scale, and it is from this day tank that the hydrofluosilicic acid is fed into the water system. A day tank is an additional safeguard against over-feeding.

Construction materials for day tanks are determined by the chemical being used, but plastics such as polyethylene are generally applicable. The tank can be provided with graduations, but are usually mounted on a scale.

Day tanks are considered part of a closed system, and the cover must be tight fitting.

2.3.4.6 Solution Tanks

The dry material discharged from a volumetric or gravimetric feeder is continuously dissolved in a chamber beneath the feeder, from whence the clear solution falls or is pumped into the water to be treated. This chamber, variously referred to as the solution pot, disolver tank, solution tank, or dissolving chamber, may be a part of the feeder or a separate entity.

The failure to produce a clear, homogeneous solution discharge from the solution tank of a dry feeder indicates that (1) the dissolving chamber is too small; (2) the detention time is too short; (3) too little solution water is being provided; (4) agitation is insufficient; or (5) dry chemical is short-circuiting and is not being adequately mixed with the water.

It has been determined experimentally that detention time (the length of time the fluoride compound, sodium fluoride, remains in the solution tank) needs to be a minimum of 5 minutes to provide a concentration which is one-fourth the maximum solubility, provided the water temperature is above 60 deg F and the chemical is in the form of a fine powder. If the chemical is in the form of crystals or the water temperature is below 60 deg F, the dissolving time should be doubled; if both, the time should be tripled (i.e., 15 minutes).

Table 2-6 on page 2-26 give the relationship between detention times and sodium silicofluoride dry feed rates.

Short-circuiting (which is the flow of water directly from the inlet to the outlet without any mixing) is essentially a problem in the solution tank design, and is more likely to occur in the smaller size tanks. The remedy, if short-circuiting does occur, is to add baffles to the tank so that the path of the chemical to the outlet of the chamber is sufficiently deflected to provide the necessary mixing for solution.

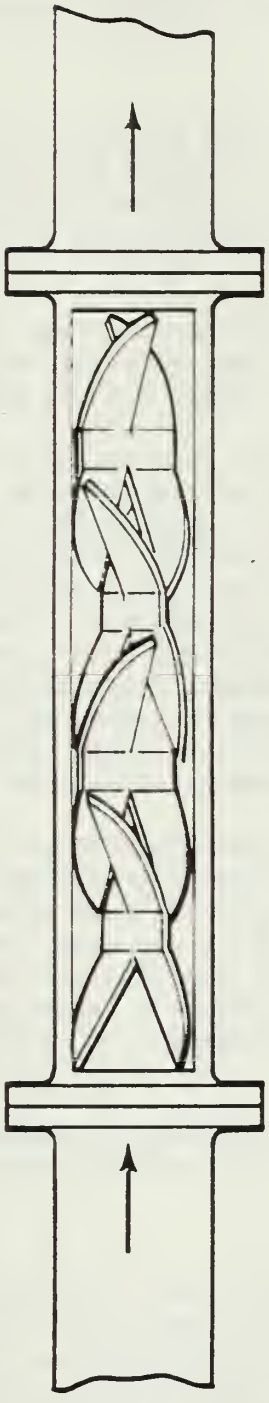
2.3.4.7 Mixers

Whenever solutions are prepared, whether it be manual preparation of sodium fluoride solutions, dilution of hydrofluosilicic acid, or the output of a dry feeder, it is particularly important that the solution be homogeneous. Slurries must not be tolerated in the feeding of fluorides, since undissolved fluoride compounds can go into solution, subsequently causing a higher-than-optimum concentration. If the fluoride compound remains undissolved, a lower-than-optimum concentration will result. Undissolved material can also result in the clogging of feeders and other devices having small openings, and if allowed to accumulate, results in considerable waste.

In the manual preparation of solutions, thorough mixing is a must. Even when a solution is being diluted, as in the preparation of hydrofluosilicic acid, specific gravities tend to stratify, and such stratification could result in feeding a solution too concentrated, or at the other extreme, plain water. Sodium fluoride is quite soluble, but even he preparation of the most dilute solutions requires sufficient agitation. Undissolved material will remain in the bottom of the solution tank while a too-dilute solution is being fed, and even if it gradually dissolves, the strong solution formed at the bottom of the tank will tend to remain in its own stratum.

While a paddle, accompanied by sufficient "elbow grease," (manual mixing) will suffice for the preparation of the dilution solution, a mechanical mixer is preferred. Mixers come in various sizes, with shafts and propellers made of various materials. A fractional horsepower mixer with a stainless-steel shaft and propeller will be satisfactory for sodium fluoride solutions, and a similar mixer with a corrosion-resistant alloy or plastic-coated shaft and propeller will handle hydrofluosilicic acid. Many times an "in-line" mixer is required. (See Figure 2-12 page 2-47).

FIGURE 2-12
TYPICAL IN-LINE MIXER



The dilution of sodium silicofluoride in the solution tank of a dry feeder can be accomplished by a jet mixer, but again a mechanical mixer is preferred. Because of the low solubility of sodium silicofluoride, particularly in cold water, and the limited retention time available for dissolution, violent agitation is a must to prevent the discharge of a slurry. Preferred materials of construction are 316 stainless-steel or plastic-coated steel.

2.3.4.8 Scales

In any fluoridation installation, except one based on a sodium fluoride saturator, scales are a necessity for weighing the quantity of dry material to be used in solution preparation, weighing the quantity of solution fed, or weighing the quantity of dry fluoride compound or hydrofluosilicic acid delivered by the appropriate feeder.

The type of scale can vary from a small household-type used for weighing a pound or two of sodium fluoride for solution preparation to a complex type with a built-in mechanism for a gravimetric dry feeder.

Most generally applicable is the platform type scale, on which can be placed a solution tank, carboy of acid, or an entire volumettric dry feeder. Although the scales may be specifically designed for this application, as are those supplied by manufacturers with volumetric dry feeders, in many cases an ordinary hardware-store type of scale will be perfectly acceptable. Some minor modifications, such as removing the wheels or rotating the beam, may be necessary, but as long as the scales have sufficient capacity and sensitivity, there is no reason why they cannot be used. Capacity and sensitivity are the only serious considerations, and the points to remember are that the scale must be capable of weighing the tank and its contents when full or the volumetric feeder and its hopper when full, with measurements to the nearest pound or better.

No particular problems should be encountered when mounting equipment on platform scales, except when there is connection to a water line, a vent line, or when the discharge line from the solution tank of a volumetric dry feeder is fixed in place. It should be remembered that this dissolving chamber, or solution tank, is also mounted on the scale platform and thus all connections to it must be flexible enough (use horizontal flexible connectors) to permit the scale to operate. Also there should be no overhang over the scale. A steel plate may be necessary.

Scales may is purchased with automatic recorders giving the pounds remaining at any time depending on the type of chart used.

2.3.4.9 Liquid Level Switches

Liquid level switches or controllers are used to automatically maintain preset (fluoride) liquid levels in a tank. They can be found in hydrofluosilicic day tanks when filled from a bulk tank, sodium fluoride upflow and downflow type saturators, and dry feeder dissolving tanks. The switches keep the tanks from going dry or overflowing, and may also be used to prevent a metering pump from running dry.

An example of one type is the common float valve in a water closet. It begins the filling process after each flush and shuts off the water supply when the tank is full.

The switch may be of the manual (lower cost) or electrical (higher cost) type.

Most newer models today are electrical (12 volt or 115 volt) and are wired to control a solenoid valve (electrically operated open-close valve), on a fill pipe or metering pump. Several different types are on the market today and work on different principles, such as, mercury switches, air pressure, electrodes, conductivity, and encapsulated reed switches.

The manual type require no electricity and use water pressure or a float valve to activate a type of ball cock.

Liquid level switches are adjustable and the high and low levels may be changed as necessary, however, the high liquid level must be set below the overflow pipe. The overflow should terminate in an airgap arrangement so the operator will notice any malfunction and take steps to prevent any overflowing.

2.3.4.10 Unions

Unions are important in fluoride piping and are a type of plumbing fitting. They are used for joining pipes or tubing that you expect to disconnect at a later date for maintainance or repair purposes. Unions save time and money when removing or disconnecting any fixtures for repair or replacement.

Unions may be constructed of many materials, such as, bronze or PVC, and should be compatible with the liquid in the pipe.

Unions are recommended on a saturator system, especially when it must be removed, drained, and cleaned as necessary. The cleaning process requires disassembly of the 3/4 inch overflow pipe, submerged make-up water line to upflow saturator, and make-up water line inlet to saturator. All the above connections should have unions.

Other places to consider placing unions are adjacent to a softener, small water meter, and reduced pressure backflow preventer if so equipped on a saturator make-up water line, and adjacent to any metering pump if plastic pipe is used.

Unions may also be used to join tubing together on a discharge line, and are sized as small as one - quarter inch. Plastic ball valves may be bought as single union or double (true) union at a higher cost.

Prices of unions are relatively inexpensive and are sometimes referred to as a "plumber's helper".

2.3.4.11 Cross Connection Control Services - Anti-Siphon Valves

All states including Massachusetts require an anti-siphon (also called back-pressure) valve or spring located on the discharge side of the fluoride metering pump wherever a fluoride solution is added to any pipeline, channel, or clearwell.

Of all the auxiliary equipment used, the anti-siphon valve is probably the most important from a safety viewpoint. The lack of an anti-siphon valve has resulted in several overfeeds in the country which could have been prevented.

The anti-siphon valve is different from an atmospheric or non-pressure type vacuum breaker which is discussed separately, and the two must not be confused.

The purpose of the anti-siphon valve is to prevent a potential overfeed of fluoride which could occur when the metering pump is not pumping or unplugged. It prevents dynamic siphoning (free wheeling) and flow-through when suction pressure exceeds discharge pressure.

Always install an anti-siphon valve on the discharge (pressure) side of the metering pump head and accessible for observation and cleaning. Do not install it where it will be under water or out of sight.

The theory of operation is that a spring must be compressed whenever the pump diaphragm strokes or allows fluoride solution through. Usually the spring is protected by a hypalon or teflon diaphragm, but not always. The diaphragm type anti-siphon valve is better because the spring itself is protected from the fluoride solution, especially acidic hydrofluosilicic acid.

Some anti-siphon valves are adjustable by turning a screw and some are pre-set at the factory. Most are set in the range of 15 - 20 pounds per square inch (psi).

Some anti-siphon valves are built into the pump head, but most are considered additional and must be purchased separately. Always check with the pump manufacturer or distributor to inquire that it is present, and never remove one.

A smart operator will inspect the anti-siphon valve spring for wear annually, keep a spare on hand, and replace as directed by the manufacturer.

2.3.4.12 Cross Connect Control Devices Backflow Preventers on Water Lines

Since the usual arrangement for a solution tank on a dry feeder or an upflow saturator is to have the water inlet below the outlet (submerged connection), there is a cross connection which requires adequately safety measures. If a break occurs in the water line (negative pressure), concentrated fluoride solution could be drawn back (sucked) into the water line.

Remember the fluoride concentration in the top of the saturator is very high at 17,600 ppm or 4% NaF.

To prevent the reverse flow of fluoride solution into the water line, a device is placed in the pipeline to protect the water supply. The type of device is called a reduced pressure backflow preventer and is usually sized 3/4 to 1 inch.

The Department of Environmental Quality Engineering (DEQE) has regulations governing the type of device, size, manufacturer and model number, installation procedure, and testing of reduced pressure backflow preventers. You are urged to consult their regulations (310 CMR22.22(1-10)] which are available for a small fee from the Secretary of State's Bookstore Room 116, State House Boston. More information may be obtained by calling 617 727-2834.

For dry feeders approved prior to 1975, a non-pressure type vacuum breaker may be used as protection against reverse water flows caused by negative pressure or back-siphonage. It should be installed on the water inlet as near as possible to the point of entry. If there is a solenoid valve or manually operated valve on the water inlet line, the vacuum breaker must be installed between the valve and tank.

For utmost safety to prevent back siphonage, the vacuum breaker must be installed as close to the solution tank as possible, and in particular elevated 6 inches above the lip of the tank.

2.3.5. Costs

As in all engineering, cost plays a very important role in the selection of the fluoridation system to be installed. Higher initial equipment costs can sometimes be justified by lower operating chemical costs. This is often the case in larger communities where dry feeders or bulk acid installations can be justified by the lower cost of sodium silicofluoride or hydrofluosilicic acid in bulk quantities. Conversely, in smaller systems using relatively small amounts of chemicals, the cost of more expensive chemicals such as sodium fluoride or hydrofluosilicic acid in small quantities is not as significant as initial installation costs, and saturators or direct feed from carboys is advantageous.

In order to make a preliminary cost estimate for a fluoridation system, it is necessary to know the number and arrangement of sources supplying water to the system, the annual average water production of each source, the natural fluoride content of each source, and whether or not flow pacing is required. From this information the number of injection points, equipment, and chemical type can be selected and preliminary designs and cost estimates prepared.

A strong word of caution is necessary at this point. Costs and cost estimates are highly variable factors. Especially variable are rules of thumb and "national figures." Costs vary widely depending on local conditions, shipping, availability, and many other factors (some of which may be unknown except locally). Thus, the cost information given

Table 2-7

FLUORIDATION EQUIPMENT COSTS

Items	1984 Costs (Dollars)
1. Feeders	
Volumetric	$3,000 - 18,000
Gravimetric	8,000 - 20,000
Saturator	450 - 900
2. Diaphragm, piston pumps	600 - 3,000
3. Electronic pumps	400 - 1,500
4. Pacing meters (3/4" - 4")	300 - 5,000
5. 3/4 inch reduced pressure backflow preventers	110 - 200
6. Metering pump anti-siphon valves	20 - 100
7. Storage	$1.00 - $2.00 per gallon of storage.

Table 2-8

MA FLUORIDE CHEMICAL COSTS (AWWA STANDARDS)

Items	1984 Cost/lb. as received
1. Sodium fluoride	$0.54 - $0.80
2. Sodium silicofluoride	$0.22 - $0.45
3. Hydrofluosilicic acid	
a. Bulk purchases	$0.06 - $0.15
b. Carboys and drums	$0.08 - $0.25

Table 2-9

TEST EQUIPMENT COSTS

Items	1984 Costs (Dollars)
1. Ion electrode equipment	
a. Ion electrode (meter)	$600 - 1,500
b. Fluoride electrode	250 - 400
c. Reference electrode	60 - 100
d. Magnetic stirrer	50 - 100
2. SPADNS equipment	
a. Colorimetric (Lab model-photometer)	$300 - 900
b. Colorimetric (Field test Kit photometer)	200 - 1,600
c. Spectrophotemeter	800 - 1,600

2.3.5.4 Installation Costs

This is by far the most difficult figure to determine. Some States install most of the equipment themselves; others contract for the entire installation. Local costs of installation vary greatly. Installation costs must be determined individually, based on local practices, regulations and codes, labor, and material costs.

2.3.5.5 Test Equipment Costs

From Table 2-9 on page 2-53 it is apparent that the test equipment costs are dependent upon the method selected. For analytical support via an approved method, the cost will be between $1,000-$2,000. Keep in mind that field test results must periodically be verified either locally or in State laboratories by standard approved methods. Costs are listed with 1984 references.

2.4 Fluoridation Systems- calculations

2.4.1 General

To realize the full benefits of fluoridation, it is very important that the optimum fluoride content be consistently maintained in the drinking water supply. To insure constant fluoride feed, proper operation of the fluoridation equipment is essential. Experience has shown that the basic reason for low or erratic fluoride levels is due to poor operation and maintenance.

Adjusting the fluoride level in a water supply to an optimum level is accomplished by adding the proper concentration of a fluoride chemical at a consistent rate. To calculate the feed rate for any fluoridation feeder in terms of pounds of fluoride to be fed per day, it is necessary to know the following information about the system:

1. The proper dosage.

2. The plant rate or the pumping rate.

3. The commercial purity and the fluoride ion concentration of the fluoride chemical being fed.

Once this information has been obtained, the fluoride feed rate can be calculated by using the pounds formula (See Section 2.4.6 on page 2-57).

Another method used to calculate the fluoride feed rate is to use a ratio as Dr. Ervin Bellack does in his "Fluoridation Engineering Manual" on page 42: The equation, $R_1 \times C_1 = R_2 \times C_2$ (water flow rate times fluoride level desired equals solution feed rate times fluoride concentration of the solution), should be used to calculate the theoretical mean fluoride concentration for a given time interval. Obviously, accurate figure for weights or volumes of materials used are necessary for accurage calculations. The use of appropriate units (which can be cancelled arithmetically) will produce a calculated result in the desired units and will verify the proper insertion of figures into the equation.

2.4.2 Optimum fluoride Level

To find the optimum level of fluoride, the annual average of the maximum daily air temperature must be known. The local U.S. Weather Bureau office can be called to obtain this temperature data for the last five years. The average of these five temperatures will give the annual average maximum daily air temperature for five years. With this information, obtain the optimum fluoride concentration in the drinking water from the chart give below:

Annual Average of Maximum daily air temperature - F[1]	Recommended fluoride conc. in milligrams per liter
50.0 - 52.7	1.2
52.8 - 58.3	1.1
58.4 - 63.8 <--(Massachusetts)---------->	1.0
63.9 - 70.6	0.9
70.7 - 79.2	0.8
79.3 - 90.5	0.7

[1]Based on temperature date obtained for a minimum of five years.

In most States, the State officials in the water supply program will know what the optimum fluoride level should be for each drinking water supply system.

2.4.3 Dosage

The dosage, expressed as milligrams per liter (mg/l) or parts per million (ppm), is obtained by subtracting the natural fluoride level from the desired occurring fluoride level present in the water supply at the point of injection. For example, if the desired fluoride level is 1.0 mg/l and the natural fluoride level is 0.1 mg/l at the point where the fluoride chemical is to be added, the fluoride dosage is:

Dosage, mg/l = Optimum level, mg/l - Natural level, mg/l
= 1.0 mg/l - 0.1 mg/l
= .9 mg/l

The unit of expression, milligrams per liter is used in laboratory work to indicate very small concentrations. It is a weight/volume relationship and milligrams per liter and parts per million may be used interchangeably as long as the liquid density is 1.0 grams per cubic centimeter. A concentration of 1 mg/l or 1 ppm means that there is 1 part of substance by weight for every 1 million parts of water. A concentration of 10 mg/l would mean 10 parts of substance per million parts of water.

2.4.4. Pumping Rate

The pumping rate or the plant flow rate is also known as the rate of production. In all larger water treatment plants, there will be meters to determine the rate of production, usually measured in millions of gallons per day (MGD). Generally, the smaller water system will have a master meter where the water pumped can be read directly. If there is no master meter, then the pumping capacity of the pump can be used (although this is a rather poor method of measuring the plant rate).

There is a difference between the pumping rate (rate of production) and the quantity of water used per day. For example, if the master meter of the well pump indicates a pumping rate of 2 MGD, but the well or water plant is in operation only 6 hours per day, then the quantity of water used is 0.5 MGD. This is because the pump operated only 1/4 of a day (24 hours ÷ 6 hours). The pumping rate, 2 MGD, is what must be used to calculate the fluoride feed rate, not the quantity of water used that day.

To calculate the fluoride feed rate in pounds per day, it is necessary to convert the pumping rate to millions of gallons per day, MGD. This is done by multiplying the plant rate by the necessary arithmetic units to yield gallons per day and then dividing that value by one million. For example, a pumping rate of 200 gallons per minute equals:

$$\text{Plant rate, MGD} = \frac{\text{Gallons/min} \times 1440 \text{ min/day}}{1{,}000{,}000}$$

$$= \frac{200 \text{ gal/min} \times 1440 \text{ min/day}}{1{,}000{,}000}$$

$$= .288 \text{ MGD}$$

2.4.5 Chemical Purity and Available Fluoride Ion Concentration

We know that it is the fluoride ion from which we obtain dental benefits. There are several chemical compounds used today which form fluoride ions in a water solution and also meet water quality standards. Since fluoride is found only in combination with other elements, for each respective fluoride compound there will be only a certain percentage of that compound that is actually fluoride ions. These chemical compounds are not 100 percent pure and therefore this is another value which must be accounted for to accurately assess the fluoride dosage. The percent fluoride ion available and the commercial purity of the common fluoride chemicals is as follows (a more accurate value should be obtained from your supplier):

Percent of Fluoride Ion	
Sodium Fluoride	45.3% = .45
Sodium Silicofluoride	60.7% = .60
Hydrofluosilicic Acid	79.2% = .79

Commercial Purity*	
Sodium Fluoride	98% = .98
Sodium Silicofluoride	98% = .98
Hydrofluosilicic Acid	23% = .23

*Just one figure was selected

The percent available fluoride ion is multiplied by the commercial purity for each compound. This value indicates how much fluoride is available in that particular chemical compound. For example, sodium fluoride contains 45 perent F - and has a commercial purity of 98 percent to yield:

$$\begin{aligned} \% \text{ available fluoride} &= \% \text{ F-} \times \% \text{ commercial purity} \\ &= .45 \times .98 \\ &= .44 \end{aligned}$$

The percent available fluoride is divided into the pounds formula, discussed below.

2.4.6 The Pounds Formula

A very comprehensible method of determining feed rate in pounds per day for any chemical compound used in water treatment is the pounds formula. You must know the dosage desired in mg/l, the plant rate in MGD, and in the case of fluoride, the percent available fluoride present in the respective fluoride chemical fed. The basic formula is:

$$\text{lbs/day (pound per day)} = \frac{\text{mg/l (dosage)} \times \text{MGD (plant rate)} \times 8.34 \text{ lb/gal}^*}{\% \text{ F-} \times \% \text{ commercial purity}}$$

*This is the weight of 1 gallon of water. By using this conversion factor, you are able to convert the plant rate to pounds per day.

The pounds formula is easily manipulated to determine dosage. Success in using the pounds formula depends on keeping track of arithmetic units and cancelling these units as necessary. To develop the formula for dosage, divide both sides by MGD x 8.34 lbs/gal; now multiply both sides by the percent available fluoride to yield the formula for dosage:

$$\text{ppm or mg/l} = \frac{\text{lbs/day x \% available fluoride}}{\text{MGD x 8.34 lbs/gal}}$$

This dosage formula is the basis for the development of the TA formula which is discussed ahead.

2.4.7 Methods of Calculating Theoretical Fluoride Averages in Fluoridated Public Water Supplies in Massachusetts for Na F or Sodium fluoride

1. For Na F saturator (upflow or downflow) and Na F dry feeders use this formula:

$$\text{T.A. (\#)} = \frac{P}{GC}$$

2. For Na F saturators equipped with make-up water meters use this formula:

$$\text{T.A. (gals.)} = \frac{M\ I}{GC\ I} \quad \text{or} \quad \text{T.A. (C.F.)} = \frac{M\ 2}{GC\ 2}$$

Explanation of Symbol

T.A. (#) = Theoretical fluoride average in p.p.m. based on pounds (#) added per unit time. (Usually a month or two)

P = Pounds (#) Na F added to saturator or dry feeder per unit time

G = Gallons of water fluoridated, in million gallons per unit time (Use same unit time as P, Ml, or M 2)

C = constant = 16.9
(16.9 = (8.34/0.98 x .452) x 0.9)

T.A. (gals) = Theoretical fluoride average in p.p.m. based on gallons make-up water used per unit time

M 1 = Make-up water added to saturator in gallons per unit time
C 1 = constant = 50
(50 = (1,000,000/40,000 x .452) x 0.9)

T.A. (C.F.) = Theoretical fluoride average in p.p.m. based on cubic feed (C.F.) make up water used per unit time.

M 2 = Make-up water added to saturator in cubic feed per unit time

C 2 = constant = 6.7
(6.7 = (1,000,000/40,000 x .452) x 0.9 ÷ 7.48)

Assumption and Known Facts

1. The natural fluoride level is 0.1 ppm (Mass. state average)
2. The commercial purity of Na F is 98% (2% inert ingredients)
3. Na F is 45.2% fluoride by weight at 100% purity
4. The maximum solubility of a saturated Na F solution is 4.0% or 40,000 p.p.m.
5. The optimum fluoride level is 1.0 ppm

Example

A Massachusetts well produces 1 mgd every day and fluoridates using a NaF saturator. The operator says 500 # Na F was added and 1450 gallons of make-up water was used last month. Did be fluoridate adequately: (Assume 31 day month and 98% commercial purity for Na F)

P = 500 C = 16.9
G = 1.0 x 31 = 31.0 C 1 = 50
M 1 = 1450 Unit time = 31 days

$$\text{T.A. (\#)} = \frac{P}{GC} = \frac{500}{31.0 \times 16.9} = 0.96 \text{ ppm F average}$$

$$\text{T.A. (gals)} = \frac{M\ 1}{GC\ 1} = \frac{1450}{31.0 \times 50} = 0.94 \text{ ppm F average}$$

The operator was successful.

2.4.8 Methods of Calculating Theoretical Fluoride Averages in Fluoridated Public Water Supplies in Massachusetts for H_2SiF_6 or Hydrofluosilicic Acid

1. For H_2SiF_6 feeders using a scale use this formula:

$$\text{T.A. (\#)} = \frac{P}{GC_4}$$

2. For $H_2S_iF_6$ feeders using a gallon graduated container and no scale use this formula:

$$\text{T.A. (gal)} = \frac{G1}{GC_5}$$

Explanation of Symbols

T.A. (#) = Theoretical fluoride (F-) average in p.p.m. based on pounds (#) H_2SiF_6 added per unit time (Usually a day, week, or month)

P = Pounds H_2SiF_6 added to the water per unit time

G = Gallons of water fluoridated in million gallons per unit time (Use same unit time as P or G_1)

C_4 = Constant which depends on commercial purity of H_2SiF_6 used (See following table) = (8.34 x 0.9) / .791 (P/100)

C_5 = Constant which depends on commercial purity of H_2SiF_6 used (See following table) = C_4/(8.34 x SP.GR.)

T.A. (gal.) = Theoretical fluoride (F^-) average in p.p.m. based on gallons H_2SiF_6 added per unit time (Usually a week to a month)

G_1 = Gallons (gal.) H_2SiF_6 added to the water per unit time.

Table of Values for C_4 and C_5

Commercial Purity (P) of H_2SiF_6 in %	C_4	C_5
22	43.1	4.29
23	41.2	4.10
24	39.5	3.91
25	37.8	3,70
26	36.5	3.55
27	35.1	3.40
28	33.9	3.26
29	32.7	3.12
30	31.7	3.02

Assumptions and Known Facts

1. The natural fluoride level is 0.1 ppm (Mass. state average)
2. The commercial purity of H_2SiF_6 ranges from 22-30% (Rest mostly water)
3. The optimum fluoride level is 1.0 ppm.

Example

A Mass. filtration plant fluoridated 4,500,000 gallons of water per day for the first 15 days and 5,000 ,000 gallons of water per day for the last 15 days of the month. The operator says 5,000 pounds of 30% H_2SiF_6 was added to the water that month. Did he fluoridate adequately?

P = 5,000
G = (15 x 4.5) + (15 x 5.0) = 142.5 (Round off to 143)
C_4 = 31.7 (From table with P = 30%)
Unit time = 30 days

$$\text{T.A. (\#)} = \frac{P}{GC_4} = \frac{5{,}000}{143 \times 31.7} = 1.10 \text{ ppm } F^- \text{ average}$$

The operator was successful.

2.4.9 Method of Calculating Theoretical Fluoride Average in Fluoridated Public Water Supplies in Massachusetts for $Na_2 SiF_6$ or Sodium Silicofluoride

1. For $Na_2 SiF_6$ dry feeders use this formula:

$$\text{T.A. (\#)} = \frac{P}{GC_3}$$

Explanation of Symbols

T.A. (#) = Theoretical fluoride average in p.p.m. based on pounds (#) added per unit time (Usually a day, week, or month)

P = Pounds (#) Na_2SiF_6 added to dry feeder per unit time

G = Gallons of water fluoridated, in million gallons per unit time (Use same unit time as P)

C_3 = constant = 12.4
(12.4 = (8.34/0.99 x 0.607) x 0.9)

Assumptions and Known Facts

1. The natural fluoride level is 0.1 ppm (Mass. State average).
2. The average commercial purity of Na_2SiF_6 is 99% (1% inert ingredients).
3. Na_2SiF_6 is 60.7% fluoride by weight at 100% purity.
4. The optimum fluoride level is 1.0 ppm.

Example

A Massachusetts water treatment plant produces 12.0 mgd every day and fluoridates using a Na_2 SiF_6 dry feeder. The operator says 4,000 pounds Na_2SiF_6 was added last month. Did he fluoridate adequately? (Assume 31 day month and 99% commercial purity for Na_2SiF_6).

P = 4,000 C_3 = 12.4
G = 12.0 x 31 = 372 Unit time = 31 days

$$\text{T.A. (\#)} = \frac{P}{GC_3} = \frac{4,000}{372 \times 12.4} = \text{0.87 ppm F average}$$

The operator was partially successful since the average was a little on the low side.

2.4.10 Method of Checking Metering Pump Accuracy Using Calibration Chamber

It is recommended that a small calibration chamber be placed in the suction line of a metering pump for sodium fluoride and hydrofluosilicic acid installations. The calibration chamber will assist the operator when setting the discharge or stroking rate of the pump.

The chamber is constructed of clear plastic or polypropylene and long enough to accommodate (500 - 1,000) milliliters (ml) with 10 ml subdivisions. The top is open to allow easy filling of water for calibration purposes. The chamber is secured to a wall or other suitable place, and mounted higher than the metering pump for a flooded suction condition.

A 1/2 inch PVC ball valve or shut off valve is placed on the bottom tee to isolate the calibration chamber when not in use.

1. For NaF or H_2SiF_6 use this formula

GPD = .38M

EXPLANATION OF SYMBOLS

GPD = Gallons per day that metering pump pumps for a 24 hour continuous period

M = ml of water used in 1 minute

NOTE: 1 gallon = 3789 ml, 1 oz. = 29.6 ml

EXAMPLE

An operator uses 25% hydrofluosilicic acid and his record shows that 16 gallons were used yesterday when 3,500,000 gallons of water were produced. His reading of the calibration chamber indicates 43 ml of water was consumed in 1 minute. How would you interpret the readings?

M = 43

GPD = .38 M = .38(43) = 16.3

The calculated value of 16.3 gallons of fluoride per day agrees very closely with the actual amount of hydrofluosilicic acid consumed at 16 gallons. Therefore the metering pump was pumping continuously at 43 ml per minute.

Chapter Three
DESIGN OF FLUORIDATION SYSTEMS

3.1 Introduction

The engineering aspects of fluoridation have been discussed, including fluoride chemicals, fluoride equipment, and calculating fluoride feed rates. Now all these parts should be combined in a specific fluoridation system.

Among the considerations in designing the right fluoridation system for a particular situation are: water usage rate (population served), chemical availability, cost, type of operating personnel available, and just plain personal preference on the part of the person or persons making the decision. While there is no specific type of fluoridation system which is solely applicable to a specific situation, there are some general limitations imposed by the size and type of water facility. For example, a large metropolitan water plant would hardly be likely to consider a fluoridation installation involving the manual preparation of batches of solution any more than would a small facility consisting of one unattended well consider the use of a gravimetric dry feeder installation.

For the smallest water plant, some type of solution feed is almost always selected. There is almost no lower limit to the ranges of the small metering pumps, and even if the feed rate for solution were impractically low, a more dilute solution would solve the problem. Conversely, there is almost no upper limit to the capacity of volumetric or gravimetric dry feeders. For all those water plants in between, there will be a choice, modified only by individual circumstances.

3.2 Preliminary Design (Chemical Selection)

3.2.1 General

Prior to the actual design of a fluoridated system, a decision must be made on the type of chemical to be used. This will largely determine the type of fluoridated water system that will be designed.

For the smaller water supply systems, the amount of chemical used is small enough so that the cost per pound of chemical is not as important as the equipment costs. Thus, either sodium fluoride or hydrofluosilicic acid, even though relatively expensive in small lots, can be used. The decision of whether to use a manually prepared sodium fluoride solution, a saturator, diluted or undiluted hydrofluosilicic acid depends on the quantities to be fed, the skill of the operator, the availability and desirability of acid, and personal preference.

Perhaps the simplest fluoridation installation is one based on the use of hydrofluosilicic acid. The acid is supplied in carboys or drums, which are mounted on a platform scale. A solution feeder, mounted on a shelf above the carboy, draws acid and injects it into a water main in proportion to the water flow. An anti-siphon valve is usually part of the feeder.

If the supply is too small to utilize undiluted hydrofluosilicic acid, a sodium fluoride solution or diluted acid feeding system is almost as simple. The equipment would be essentially the same as the acid feeding system, plus that needed for dilution or solution preparation. However, it is the general consensus of most engineers that diluting acid is an undesirable practice, due to errors in making the dilution and the increased safety hazards to the operator from the increased handling required.

Except for the fact that solution strength may be relatively high (4 percent), the use of a sodium fluoride in a saturator provides the basis for an extremely simple and virtually fool-proof solution-feed installation. Once the solution feeder has been adjusted, the only operator attention required is the occasional replenishing of chemical (without weighing) and cleaning of the saturator.

Sodium silicofluoride is limited to water plants large enough to accommodate a volumetric or gravimetric feeder. It is always fed as a dry feed. Only larger water treatment plants would have the capacity for dry feeders.

Fluoride chemicals are plentiful, but having the right one in the right place at the right time may not be as simple as it might seem. The availability of compounds derived from phosphate fertilizer production, hydrofluosilicic acid, and sodium silicofluoride is tied in with fertilizer sales, so, if there is a decline in such sales, there is a decline in recovery of the fluoride compounds. Such occurrences are rare and can be circumvented in large measure by purchasing these chemicals on a contract basis. Most suppliers will preferentially deliver to contract customers when there is a shortage. Sodium fluoride is derived from fluorspar, so it is not tied in with fertilizer production.

In any case, it would be wise to investigate the availability of fluoride chemicals through a local supplier before making a choice. Ordinarily, stocks of chemicals on hand at local distributors' warehouses are sufficient for the smaller water plants even if there is a temporary shortage. It is the large user of hydrofluosilicic acid who must be assured of an ample supply before committing himself to an installation designed around the use of the acid for fluoridation. An on-site visit is necessary, especially if the design is really an extension of an existing system.

3.2.2 Problems

To determine the type of fluoride chemical used and thus the type of fluoridation system to be designed, the following items must be considered:

1. Water usage
2. Chemical availability
3. Type of existing facilities (compatibility)
4. Space available
5. Number of treatment sites required (fluoride injection points)
6. Characteristics of the water
    a. Natural fluoride and optimum fluoride levels
    b. Type of flow (variable or steady state)
    c. Pressure (discharge)

7. Estimated overall cost
   a. Capital (initial) cost
   b. Operation and maintenance costs
   c. Chemical costs
8. Operator preference
9. State rules, regulations, and preference

There are other considerations that may be necessary in particular situations - for example, the technical issues that may surface in a fluoridation referendum. The selection of the chemical is a judgement made from considering some or all the above items. The following various examples will illustrate how the fluoride chemical selection should be made.

PROBLEM 3-1

A small city in southern Iowa has a population of 2,540 people. They have two wells with well pumps with the capacities of 352 gpm and 410 gpm, respectively. One well is north of town and the other well is south of town. The average water supply used is 0.25 MGD (million gallons/day). The well houses are large, but have chlorination equipment in them. The raw water has a natural fluoride level of 0.2 ppm and is not considered corrosive. The optimum level of fluoride in southern Iowa is 1.0 ppm. What type of fluoride chemical should be used in this town?

SOLUTION 3-1

As the town has two relatively small wells that are not attended on a full-time basis, the choice of sodium silicofluoride and dry sodium fluoride for dry feeders should be ruled out immediately. Thus, the choice is using sodium fluoride and a saturator or using a hydrofluosilicic acid and a solution feeder.

A saturator will require slightly more space, but that is no problem here. Both the acid system and the saturator system are compatible with the water system. The characteristics of the water are such that adding 0.8 ppm fluoride, a steady flow, and adequate pressure are no problem. There will be two fluoride injection points, one at each well, because of the location of the wells.

While we will assume both chemicals are readily available, there will be a difference in cost. Also, capital costs will be different. These costs should be compared and evaluated:

Water usage = 0.25 MGD

Chemical used:

$$NaF = \frac{19\ lb}{1\ MG \times ppm} \times 0.8\ ppm \times 0.25\ MGD \times 365\ days/yr =$$

$$NaF = \underline{1,386\ lb/year}$$

$$\text{Acid } 23\% = \frac{46\ \text{lb}}{1\ \text{MG} \times \text{ppm}} \times 0.8\ \text{ppm} \times .25\ \text{MGD} \times 365\ \text{days/yr} =$$

Acid 23% = 3,358 lbs/year

	CHEMICAL COST	YEARLY COST	EQUIPMENT COSTS (ea.)	INSTALLATION COSTS (ea.)	TOTAL CAPITAL COSTS
NaF	60c/lb	$830	$1,500	$1,500	$6,000
Acid	8c/lb	$270	$ 800	$1,200	$4,000

The difference in capital cost of $2,000 plus the difference in yearly chemical costs of $560 makes the acid feed system look very attractive. A judgement could be made based on cost; thus, the best judgement (based solely on costs) would be to use the hydrofluosilicic acid system.

Now, the other intangible factors must be considered. The State water supply program prefers diluting acid in smaller fluoridated systems if acid is used. Thus, the capital and operational costs of the acid system will increase a small amount. But the costs probably would still be favorable for using acid. Use of diluted acid will greatly increase the operator's time at the well site and present the problem of obtaining an accurate dilution each time the acid is mixed. Thus, because of these problems, especially the latter, the saturator should be preferred. The chemical choice in this problem is the sodium fluoride for a saturator.

PROBLEM 3-2

Assume a large metropolitan city in a northern State wants to fluoridate. The source of supply is a river which only has a natural fluoride content of 0.1 ppm. The optimum level of fluoride in the State is 1.2 ppm. The population of the city is 850,000 with a daily average water usage of 75 MGD. What type of fluoride system should be used?

SOLUTION 3-2

With this large amount of a water usage, a saturator and sodium fluoride can be ruled out. Thus, sodium silicofluoride or hydrofluosilicic acid should be considered. Space should be no problem with a water treatment plant. With other dry feeders at the plant, compatibility should not be a problem. Only one injection point would be needed. The characteristics of the water should be no problem, except there will be variable flow and the water may be corrosive.

Assume the State rules and regulations allow the use of either acid or sodium silicofluoride. The water plant operators probably won't care which one is used. Thus, the decision comes down to basically costs, availability, and the question of corrosive water.

The cost of each system is as follows:

Water usage = 75 MGD

$$\text{Acid} = \frac{46\ \text{lb}}{\text{MG} \times \text{ppm}} \times 75\ \text{MGD} \times 1.1\ \text{ppm} \times 365\ \text{days/yr} =$$

Acid 23% = 1,385,175 lbs/yr

$Na_2SiF_6 = \frac{14 \text{ lb}}{\text{MG x ppm}}$ x 75 MGD x 1.1 ppm x 365 days/yr =

NaSiF = 421,575 lbs/yr

	CHEMICAL COST	YEARLY COST	EQUIPMENT COSTS (ea.)	BULK STORAGE	INSTALLATION COSTS (ea.)	TOTAL CAPITAL COSTS
Acid 23%	4c/lb	$55,400	$3,000	$4,000	$2,000	$ 9,000
Na_2SiF_6	20c/lb	$84,000	$6,000	--	$4,000	$10,000

There is almost $30,000 per year difference in cost of the chemical. The difference in capital costs is insignificant. Thus, based solely on cost, the hydrofluosilicic acid should be chosen. But let us assume that the water is very soft, has very low alkalinity (less than 10 ppm), and relatively low pH. In other words, the water is corrosive. Thus, using the acid would tend to make the water even more corrosive. Also, let's assume that the acid is harder to obtain. Remember that the acid will freeze at about 4 degrees F, so in a northern State, freezing could be a problem. Based on all these factors - costs, availability, and the characteristics of the water - the sodium silicofluoride should be selected. This is a judgement that can be altered if any of the above factors change or if our assumptions are wrong.

PROBLEM 3-3

Assume a city with a population of 20,500 is going to fluoridate. The city, in Colorado, has five wells. Well No. 5 is only used during the summer months during the tourist season. The wells have a capacity and fluoride level as follows:

WELL NO.	FLUORIDE LEVEL	CAPACITY (GPM)
1	0.4	400
2	0.4	400
3	0.2	550
4	0.2	550
5	0.1	300
		2,200 GPM

The optimum fluoride level is 1.0 ppm. The average water use is 1.8 MGD. The water is not treated except for chlorine. It is generally hard water. The discharge lines from the wells can be combined. What type of chemical should be used?

SOLUTION 3-3

This is a middle-sized town and, theoretically, any of the three fluoride chemicals could be used. But there is no treatment plant and no dry chemical feeders used. Thus, sodium silicofluoride should be eliminated as one of the fluoride chemicals. Both the acid and the sodium fluoride in a saturator are compatible with the water system. The characteristics of the water should be no problem. There is a steady state flow for each well, but when the line or lines are combined, there will be a variable flow.

The cost of five individual installations will have to be compared to one common installation. Also, the cost of the acid versus the sodium fluoride must be evaluated. The amount of chemicals used is as follows: (Assume an average of 0.3 natural fluoride for comparison costs only.)

$$NaF = \frac{19\ lb}{MG \times ppm} \times 0.7\ ppm \times 1.8\ MGD \times 365\ days/yr =$$

NaF = 8,738 lbs/yr

$$Acid\ 23\% = \frac{46\ lb}{MG \times ppm} \times 0.7\ ppm \times 1.8\ MGD \times 365\ days/yr =$$

Acid = 21,155 lbs/yr

Assume a pacing meter will cost about $2,000. A comparison of the costs for five injection points is as follows:

	CHEMICAL COSTS	YEARLY COSTS	EQUIPMENT COSTS (ea.)	INSTALLATION COSTS (ea.)	TOTAL CAPITAL COST
NaF	50c/lb	$4,370	$1,600	$1,600	$16,000
Acid	6c/lb	$1,270	$1,000	$1,200	$11,000

A comparison cost for one injection point is as follows:

	CHEMICAL COSTS	YEARLY COSTS	EQUIPMENT COSTS	PACING METER	INSTALLATION COSTS	TOTAL CAPITAL COSTS
NaF	50c/lb	$4,370	$1,800	$2,000	$2,000	$5,800
Acid	6c/lb	$1,270	$1,200	$2,000	$2,000	$5,200

There is a difference between capital costs of five injection points versus one injection point. The chemical costs are the same for each comparable chemical system. Therefore, based on capital costs, using one injection point would be preferred. However, please note, this capital cost does not include the cost of a bulk acid storage tank (if acid is used) nor does it include the cost of combining the water lines (the piping, labor, valves, etc). These items may be of major importance and vary greatly on a case-by-case basis. In our example above, we will consider these items to be of minor cost. The chemical costs for each year is significantly better for the acid system. Therefore, based just on costs, the single injection point using hydrofluosilicic acid would be the best fluoridation system.

Assume there is no problem with chemical availability, operator preference, or State rules and regulations. The space requirements for both the two types of systems is similar.

However, remember each well has different fluoride levels. Thus, if one injection point was used, each time the combination of wells changed, the level of natural fluoride could change. Again, a judgement must be made. If a certain combination of wells were used for long periods of time, then a single injection point could be used. In this case, the change in wells would have to accompany a manual change in the fluoride feeder setting. If there were frequent changes, then each well should have its own feeder. In both situations, acid should

be used. Let's assume that there would be frequent changes and thus five injection points should be selected. Therefore, with five injection points, the chemical selected would be hydrofluosilicic acid. The selection of the type of chemical that is used is very important because it usually decides the type of equipment used. Considerable thought should be given to this selection. In many instances, the chemical selection is made based solely on tradition.

3.3 Fluoride Feeder Selection

3.3.1 General

Once the fluoride chemical to be used has been decided, the choice of the fluoride feeder will become limited. If hydrofluosilicic acid is to be used, then a solution pump will be required. If a saturator (with sodium fluoride) is to be used, a solution pump is necessary. If sodium fluoride (as a dry chemical) or sodium silicofluoride is to be used, then a dry feeder is required. Only the specific type of each general type of feeder will need to be determined after the chemical has been selected. See Table 3-1 on page 3-8.

The type of solution feeder chosen for a particular fluoride installation is detemined by cost (primarily), availability, service reputation of the manufacturer or sales representative, and, again, personal preference. The types of solution feeders include the piston pumps, diaphragm pumps, the electronic pumps, and the peristaltic pumps.

If the decision is made to use a saturator, then the only choice is whether to use an upflow or a downflow saturator. Of course, the saturator is nothing more than a special application of a solution feeder. The upflow saturator has become more popular recently and generally is the preferred type, but the downflow saturator is a good system when properly designed and installed. The decision of which saturator to select is really only based on personal preference and cost. Some State personnel believe that there are less maintenance problems with the upflow saturator while other State personnel disagree.

The choice of dry feeders is a choice between the volumetric or gravimetric feeders. Almost always, the volumetric feeder is the best choice because of cost. The gravimetric feeder is the most expensive and the most accurate, but the accuracy of the volumetric feeder is sufficient for fluoridation.

The determination of the type of volumetric feeder is really only dependent on personal preference and availability of the equipment. Some volumetric dry feeders are capable of feeding at very low rates, and some of the smallest disc types, such as those used for pilot plant installations, are able to handle water rates as low as 25 gpm. But, it is not recommended that a dry feeder for fluoridation be used for flows under 100 gpm. If an open channel for feeding by gravity (from the solution tank) is not available, a centrifugal feed pump can be used for injecting fluoride solution into a main. Of course, any of the dry feeders can be used for sodium fluoride, as well as sodium silicofluoride.

TABLE 3-1
COMPARISON OF FLUORIDATION SYSTEMS

Chemical And System	Sodium Fluoride Manual Preparation	Sodium Fluoride Automatic Preparation (Saturator)	Hydrofluosilicic Acid 23-30%	Sodium Silicofluoride Or Sodium Dry Feed	
Water flow rate	Less than 500 gpm	Less than 2000 gpm	More than 200 gpm	More than 100 gpm	More than 2 MGD
Population served by system or each well of multiple-well system	Less than 5000	Less than 10,000	More than 500	More than 10,000	More than 50,000
Equipment required	Solution feeder, mixing tank, scales, mixer	Solution feeder, saturator, water meter	Solution feeder, day tank, scales	Volumetric dry feeder, scales, hopper, dissolving chamber	Gravimetric dry feeder, hopper, dissolving chamber
Chemical specifications and availability	Crystalline NaF, dust-free, in bags or drums	Downflow - coarse crystalline NaF in bags or drums. Upflow - fine crystalline NaF	– Bulk acid in tank cars – Trucks – Drums – Carboys	Powder in bags, drums or bulk	
Handling requirements	Weighing, mixing, measuring (manually)	Dumping whole bags only	All handling by pump – Bulk storage	Bag loaders or bulk handling equipment required	
Other requirements	Solution water may require softening	Solution water may require softening	Acid-proof storage tank, piping, etc.	Dry storage area, dust collectors, dissolving-chamber mixers, hopper agitators, etc.	
Hazards	Dust, spillage, solution preparation error	Dust, spillage	Corrosion, fumes, leakage	Dust, spillage, arching and flooding in feeder and hopper	

3.3.2 Problems

The problems in the previous section will be used to show how to select a specific type of feeder. The fluoride chemical has been selected; now the feeder will be selected.

PROBLEM 3-4

In Problem 3-1 on page 3-3, sodium fluoride was selected as the chemical to be used in a small town in southern Iowa. Select and size a saturator for this town. There are two wells supplying water to the town.

SOLUTION 3-4

Based on personal preference, an upflow saturator will be selected. Several companies sell upflow saturators. In Iowa, one company is Liquid Metronics Incorporated. To size a saturator, the size of the solution pump should first be determined:

Fluoride Dosage = 1.0 ppm - 0.2 ppm = 0.8 ppm

Pumping Rate_1 = 352 gpm or 506,000 gal/day

Pumping Rate_2 = 410 gpm or 590,000 gal/day

For Well Number One

Feed Rate_1 = 506,000 gal/day x 0.8 ppm

Concentration of sodium fluoride in the saturator = 18,000 ppm

$$\text{Fluoride Feed Rate}_1 = \frac{506{,}000 \text{ gal/day} \times 0.8 \text{ ppm}}{18{,}000 \text{ ppm}}$$

$\text{Fluoride Feed Rate}_1$ = 22.5 gallons per day

Look at Table 3-2 on page 3-10. Either a series "B" or series "A" electronic feeder would pump 22 gallons per day. But a feeder should be selected that will operate in the middle range. Thus, the maximum range should be about 45 gal/day. A Model B12 feeder or a Model B72 pump would be adequate. Probably the B12 pump would be cheaper and thus would be the pump selected. The discharge pressure is the primary difference. We have assumed a maximum discharge pressure of 100 psi. LMI has only one saturator that can be used with these electronic pumps - a Model 28850. This is a 50-gallon polyethylene tank.

For Well Number Two

Feed rage_2 = 590,000 gal/day x 0.8 ppm

$$\text{Fluoride feed rate}_2 = \frac{590{,}000 \text{ gal/day} \times 0.8 \text{ ppm}}{18{,}000 \text{ ppm}}$$

$\text{Fluoride feed rate}_2$ = 26.2 gallons per day

Thus, the maximum capacity of the feeder should be about 50 gal/day. A model B12 was selected for well pump number one. The same model should be used here. Also, the saturator will be Model 28850.

Table 3 - 2

TECHNICAL DATA - LMI

Specifications A

SERIES	A10		A11		A12		A13		A30		A32	
Output Capacity	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Gallons per hour	0.006	0.6	0.02	1.0	0.01	1.0	0.02	2.0	0.002	0.6	0.003	1.0
Liters per hour	0.023	2.3	0.076	3.79	0.038	3.79	0.076	7.57	0.008	2.3	0.013	3.79
ML or CC per min	0.38	38.0	1.26	63.0	0.63	63.0	1.26	126.0	0.13	38.0	0.21	63.0
Output per stroke ML or CC	0.13	0.63	0.13	0.63	0.13	0.63	0.26	1.26	0.13	0.63	0.13	0.63
Maximum Injection Pressure	75 psi		80 psi		110 psi		55 psi		75 psi		110 psi	

Specifications L

SERIES	L11		L12	
Output Capacity	Min.	Max.	Min.	Max.
Gallons per hour	3.5	35	7.0	70.0
Liters per hour	13.25	132.5	26.5	265.0
ML or CC per min	221	2208	442	4416
Output per stroke ML or CC	—	—	—	—
Maximum Injection Pressure	150 psi		150 psi	

Specifications B & D

SERIES	B11 B71		B12 B72		B13 B73		D10 D70		D11 D71		D12 D72		D13 D73		D14 D74	
Output Capacity	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Gallons per hour	0.008	1.6	0.012	2.5	0.022	4.5	0.006	1.3	0.012	2.5	0.02	4.0	0.05	10.0	0.1	20.0
Liters per hour	0.03	6.0	0.05	9.5	0.085	17.0	0.024	4.9	0.047	9.5	076	15.2	0.19	38.0	0.3785	76.0
ML or CC per min	0.5	100	0.79	158	1.42	284.0	0.4	82.0	0.783	158.0	1.26	253.0	3.16	631	6.3	1262
Maximum Injection Pressure	150 psi		100 psi		50 psi		300 psi		150 psi		100 psi		35 psi		20 psi	

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Note, the water usage in this community is 0.25 MGD; thus, if both wells are in operation, they will need to run for about 5 and 1/2 hours. Check the withdrawal rate from Table 2-4 on page 2-16. Well Number Two will withdraw 26 gallons in 5 and 1/2 hours or 4.7 gallons per hour. From Table 2-4, a minimum depth of 9 inches of sodium fluoride is needed at 40 degrees F to insure adequate fluoride saturation.

PROBLEM 3-5

Select a feeder for the city in Problem 3-2 on page 3-4. They are going to use sodium silicofluoride. In this northern city, Wallace and Tiernan is one of the companies.

SOLUTION 3-5

To feed sodium silicofluoride, a volumetric dry feeder will be chosen because the cost of the gravimetric feeder is not warranted. Thus, comparison of costs will not be necessary.

The fluoride feed rate is:

Fluoride Dosage = 1.2 ppm - 0.1 ppm = 1.1 ppm

Pumping Rate = 75 MGD

$$\text{Fluoride Feed Rate} = \frac{1.1 \text{ mg/l, (ppm)} \times 75 \text{ MGD} \times 8.34 \text{ lb/gal}}{.98 \times .607}$$

Assume 98 percent purity and .60 percent fluoride ion available

Fluoride Feed Rate = 1,200 lbs/day of sodium silicofluoride

Use screw-type volumetric feeder made by Wallace and Tiernan. (See Table 3-3 on page 3-12.) These capacities are given in cubic feet per hour. The density of sodium silicofluoride is approximately 65 lb/cu. ft.

$$\text{Fluoride Feed Rate} = \frac{1{,}200 \text{ lbs/day}}{65 \text{ lbs/ cu. ft.} \times 24 \text{ hr/day}} =$$

Fluoride Feed Rate = 0.76 cu.ft./hr

From the Wallace and Tiernan chart on page 3-12, several options are available. Remember 0.76 cu. ft./hr is the average valve. Thus, a low speed gearbox, Step 2 (8:1 ratio) and 2-1/2" screw size could be selected for a maximum capacity of 1.4 cu. ft. per hour. Also, a high speed gearbox, Step 3 (53:1 ratio) and 1-1/2" screw size could be selected for a maximum capacity of 1.8 cu. ft. per hour. Either feeder would be satisfactory.

Note: If the fluoridation equipment were to be used for only part of the day, the size of the feeder would change. For example, if the fluoride feed rate was 1,200 lb/day, but the equipment was only to be used for 12 hours, the size of the feeder would double.

TABLE 3-3
TECHNICAL DATA – W. & T.

Maximum volumetric capacities (cu ft/hr)

LOW SPEED GEARBOX

4-STEP DRIVE PULLEY		SCREW SIZE			
STEP	RATIO	¾"	1½"	2½"	4"
1	12:1	0.03	0.2	1.0	4
2	8:1	0.04	0.3	1.4	6
3	5.3:1	0.06	0.45	2.2	9
4	4:1	0.08	0.6	3.0	12

HIGH SPEED GEARBOX

4-STEP DRIVE PULLEY		SCREW SIZE			
STEP	RATIO	¾"	1½"	2½"	4"
1	12:1	0.10	0.8	4	16
2	8:1	0.16	1.2	6	24
3	5.3:1	0.24	1.8	9	36
4	4:1	0.32	2.4	12	50

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PROBLEM 3-6

Select a feeder(s) for the Colorado city in Problem 3-3 on page 3-5. There are five wells with varying fluoride contents. Hydrofluosilicic acid (23 percent) will be used as the fluoride chemical. Also, there will be five injection points.

SOLUTION 3-6

The type of feeder would be a solution pump because acid will be used. Also, because there are five injection points, five feeders will be required. Assume carboys of acid will be used. If one injection point had been used, most likely bulk storage for acid would have been preferred.

WELL NUMBER ONE

$$\text{Fluoride Feed Rate} = \text{lbs/day} = \frac{\text{dosage, mg/l} \times \text{MGD} \times 8.34 \text{ lb/gal}}{\% \text{ purity} \times \% \text{ F-}}$$

Fluoride Dosage = 1.0 ppm - 0.4 ppm = 0.6 ppm

Pumping Rate_1 = 400 gpm = 576,000 gal/day

Correction Factor = .79 x .23 = .18

$$\text{Fluoride Feed Rate}_1 = \frac{.6 \text{ mg/l} \times .576 \text{ MGD} \times 8.34 \text{ lb/gal}}{.792 \times .23}$$

$$\text{Fluoride Feed Rate} = \frac{2.87}{.18} = 15.94 \text{ lbs/day}$$

Thus, the fluoride feed rate for Well Number One would be 16 lbs/day.

Assume that the Precision feeder is desirable because the chlorinators are all Precision feeders. See Table 3-4 on page 3-14. Note, the capacity of the pumps are given as gallons per hour and the discharge pressure must be known. The "average" discharge pressure at a fluoride injection point would be from 50 psi to 150 psi. Usually, around 75 psi is considered normal. Assume for this problem, the discharge pressure would be a maximum of 75 psi. The capacity would be:

$$\text{Fluoride Feed Rate} = \frac{16 \text{ lbs/day}}{24 \text{ hr/day} \quad 10.5 \text{ lbs/gallon}} = 0.06 \text{ gal/hr}$$

From Table 3-4, a capacity of 0.12 gal/hr should be found and the maximum pressure checked.

Probably, the Electronic Pump Series No. 1000 (1-32) would be the best, based on the cost, the capacity, and the discharge pressure. Note, if the discharge pressure was much higher, this pump would not be adequate and the next largest size would be too large. Thus, a saturator should be considered.

TABLE 3-4
TECHNICAL DATA – PRECISION

PUMP CAPACITY

Pump Series	Pressure		Pump Output					Max CC/ Stroke	Shipping Weight Lbs (Approx)	Dimensions Inches (Approx)		
	Max PSI	Max kg/cm²	Max GPH	Max LPH	Max GPM	Max CC/Min	Max SPM			W	L	H
H1□□1-12□	600	42.2	5.6	21.2	.09	350	60	5.9	140	8	17½	18
H1□□1-14□	600	42.2	11.2	42.4	.18	700	120	5.9	140	8	17½	18
H2□□1-12□	400	28.1	8.8	33.3	.15	560	60	9.3	140	8	17½	18
H2□□1-14□	400	28.1	17.6	66.6	.30	1,120	120	9.3	140	8	17½	18
H3□□1-12□	125	8.8	30	113.5	.50	1,890	60	30.3	140	9	18½	18
H3□□1-14□	125	8.8	60	227	1.00	3,780	120	30.3	140	9	18½	18
H4□□1-1R□	50	3.5	110	416	1.83	6,930	60	115.5	145	9	26½	18
H4□□1-14□	35	2.4	220	832	3.67	13,860	120	115.5	145	9	26½	18
5□□1-11□	150	10.5	5.0	18.9	.08	315	37.5	8.4	45	17	15	10
5□□1-12□	150	10.5	10.0	37.8	.16	630	75	8.4	45	17	15	10
5□□1-13□	150	10.5	13.5	51.1	.22	850	101	8.4	45	17	15	10
6□□1-1□F	60	4.2	2.5	9.4	.04	160	36	4.4	21	12½	9	7
6□□1-2□F	60	4.2	5.0	18.9	.08	315	72	4.4	21	12½	9	7
7□□1-1R□	1200	84.4	5.0	18.9	.08	315	60	8.4	100	20	26	14
7□□1-14□	1200	84.4	10.0	37.8	.16	630	120	8.4	100	20	26	14
8□□1-1□	100	7.0	.83	3.1	.01	50	36	1.45	17	8½	9½	8
8□□1-2□	60	4.2	1.6	6.1	.03	100	72	1.45	17	8½	9½	8
9□□1-1□	125	8.8	2.5	9.4	.04	160	36	4.4	18	8½	10	9
9□□2-1□	125	8.8	5.0	18.9	.08	315	36	4.4	21	8½	14	9
9□□1-2□	60	4.2	5.0	18.9	.08	315	72	4.4	18	8½	10	9
9□□2-2□	50	3.5	10.0	37.8	.16	630	72	4.4	21	8½	14	9
10□□1-32□	75	5.3	.14	.53	.002	9	15	0.6	8	4½	7	9
10□□1-36□	75	5.3	.57	2.2	.009	35	60	0.6	8	4½	7	9
11□□1-32□	45	3.1	.25	.95	.004	15	15	1.05	9	4½	9	7
11□□1-36□	45	3.1	1.0	3.8	.016	60	60	1.05	9	4½	9	7
12□□1-1□	80	5.6	1.6	6.1	.03	100	72	1.4	15	7½	10	12
12□□2-1□	80	5.6	3.2	12.1	.06	200	72	1.4	15	7½	10	12
13□□1-1□	150	10.5	1.6	6.1	.03	100	72	1.4	22	7½	11	12
13□□1-1□H0	90	6.3	4.0	15.1	.07	250	72	3.5	25	7½	15	12
14□□1-11□	35	2.4	10.0	37.8	.16	630	72	8.4	30	7½	15½	11½
15□□1-1□	500	35	.25	.95	.004	15	72	.22	15	7½	13	9½
16□□1-1□	900	63	.25	.95	.004	15	72	.22	20	7½	14	9½
17□□1-58□	75	5.3	.79	3.0	.01	50	83	0.6	13	4½	11½	12½

PSI = Pounds per square inch
kg/cm² = kilograms per square centimeter
GPH = gallons per hour
LPH = liters per hour
GPM = gallons per minute
CC/Min = cubic centimeter per minute
SPM = strokes per minute

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WELL NUMBER TWO

As the feed rate and the natural fluoride level in Well Number Two is the same as Well Number One, the same type feeder can be used. Thus, Well Number Two will use a Precision Series No. 1000 (1-32) electronic feeder.

WELL NUMBER THREE

$$\text{Fluoride Feed Rate} = \text{lbs/day} = \frac{\text{dosage, mg/l} \times \text{MGD} \times 8.34 \text{ lb/gal}}{\%F^- \times \%\ \text{purity}}$$

Pump Rate = 550 gpm = 792,000 gal/day

Dosage = 1.0 ppm - 0.2 ppm = 0.8 ppm

Correction Factor = 0.792 x 0.23 = 0.18

$$\text{Fluoride Feed Rate} = \frac{.8 \text{ mg/l} \times .792 \text{ MGD} \times 8.34 \text{ lb/gal}}{.18}$$

$$\text{Fluoride Feed Rate} = \frac{3.95}{.18} = 21.94 \text{ lbs/day}$$

The Fluoride Feed Rate for Well Number Three is 22 lbs/day.

$$\frac{22 \text{ lbs/day}}{24 \text{ hr/day} \times 10.5 \text{ lbs/gal}} = 0.08 \text{ gal/hr}$$

From Table 3-4 on page 3-14, using 0.16 gallons/hour, probably an electronic feeder series 1000 (1-32) could be used, although its maximum capacity is only 0.14 gallons/day. It would be better to keep the same type of feeders on the wells, if possible.

WELL NUMBER FOUR

Same as Well Number Three. Thus, this well would also use a series 1000 (1-32) Precision feeder.

WELL NUMBER FIVE

$$\text{Fluoride Feed Rate} = \text{lb/day} = \frac{\text{dosage, mg/l} \times \text{MGD} \times 8.34 \text{ lb/gal}}{\text{correction factor}}$$

Pump rate = 300 gpm = 432,000 gallons/day

Dosage = 1.0 ppm - 0.1 ppm = 0.9 ppm

Correction factor = 0.792 x 0.23 = 0.18

$$\text{Fluoride Feed Rate} = \frac{.9 \text{ ppm} \times .432 \text{ MGD} \times 8.34 \text{ lb/gal}}{.18}$$

$$\text{Fluoride Feed Rate} = \frac{3.23}{.18} = 17.94 \text{ lbs/day} = 0.74 \text{ lbs/hr}$$

$$\frac{0.74 \text{ lbs/hr}}{24 \text{ hr/day} \times 10.5 \text{ lbs/gal}} = 0.07 \text{ gal/hr}$$

From Table 3-4 on page 3-14, using 0.14 gal/hr as the maximum capacity, the feeder selected is series 1000 (1-32). Thus, this series could be used for each of the five wells.

3.4 Installation

3.4.1 Fluoride Injection Point

The first consideration in selecting the fluoride injection point is that it must be a point through which all the water to be treated passes. In a water plant, this can be in a channel where the other water treatment chemicals are added, it can be in a main coming from the filters, or it can be in the clear well. In a well-pump system, it will be in the discharge line of a pump, if there is only one, or if there is more than one pump, it can be in the line leading to the elevated tank or other storage facility. If there is a combination of facilities, say a treatment plant for surface water plus supplemental wells, it must be a point where all water from all sources passes. If there is no such common point, it means that separate fluoride feeding installations will have to be made for each water facility.

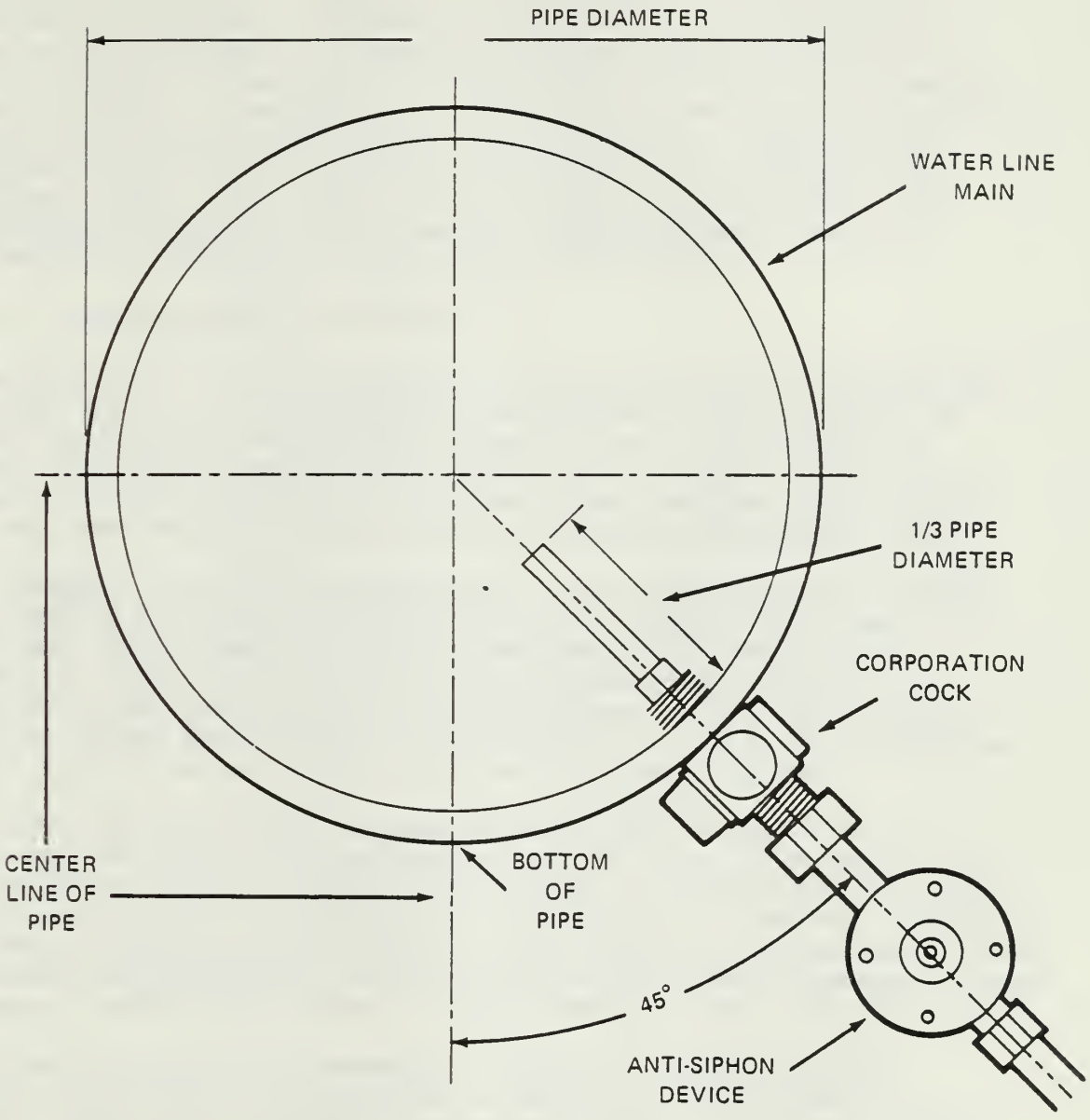
Another consideration in selecting a fluoride injection point is the question of fluoride losses in filters. Whenever possible, fluoride should be added after filtration to avoid the substantial losses which can occur, particularly with heavy alum doses or when magnesium is present and lime-soda-ash softening process is being used. There can be up to a 30 percent loss if the alum dosage rate is 100 gpm of alum. On rare occasions it may be necessary to add fluoride before filtration, such as in the case where the clear well is inaccessible or so far away from the plant that moving chemicals would be uneconomical.

When other chemicals are being fed, the question of chemical compatibility must be considered. If any of these other chemicals contain calcium, the fluoride injection point should be as far away as possible in order to minimize loss of fluoride by precipitation. For example, if lime (for pH control) is being added to the main leading from the filters, fluoride can be added to the same main but at another point, or it can be added to the clear well. If the lime is being added to the clear well, the fluoride should be added to the opposite side. Another factor in selection of injection point is the desirability of having the feeder as close to this point as possible.

The need for mixing sometimes can be a consideration in the selection of a fluoride injection point. A fluoride injection point should not be located immediately upstream from a consumer service line, a sampling tap (for testing), or a location where other chemicals are fed. These locations should be avoided. If that is not possible, an in-line mixer may be required.

The location of the fluoride injection point should be 45 degrees from the bottom of the pipe and protrude 1/3 of the pipe diameter into the pipe. A valve or corporation cock should be part of the injection point installation. See Figure 3-1 on page 3-17.

FIGURE 3-1
FLUORIDE INJECTION POINT



3.4.2 Location of Feeder

Before a type of feeder can be selected, sufficient and appropriate space for its installation must be provided. If there is an existing water plant, where other water treatment chemicals are being fed, usually space for an additional feeder is no problem. If there is no treatment plant, as is often the case with well supplies, then there may be a well house, or perhaps even some type of shelter near an elevated storage tank. The feeder must be placed in a dry, sheltered area, near to the point of fluoride injection, and preferably in a place which has storage space for chemicals. There must be electrical power available, in most cases, and a water line for solution preparation, unless undiluted hydrofluosilicic acid will be used. The location must be accessible for chemical replenishment and maintenance. Other than these basic requirements, consideration should be given to the desirability of isolation of chemical storage from other materials, for adequate ventilation, and for general convenience.

3.4.3 Solution Feeder Installations

A solution feeder should be placed above the solution container, if at all possible, to lessen the chances for siphoning. The suction line should be as short and straight as possible, and there should be a foot-valve and strainer at the bottom, if necessary, to weight it down. Weights usually furnished with solution feeders are made of porcelain, but any heavy material which is resistant to the solution may be used.

The discharge line from the feeder should also be as short and straight as possible, but circumstances may sometimes require that a long discharge line be used. If such is the case, try to avoid sharp curves or loops in the line. Injecting solution into the top of a pipe should be avoided since air collects there and can work its way into the feeder check valve or the discharge line and cause air-binding. There should be an anti-siphon valve at the injection point.

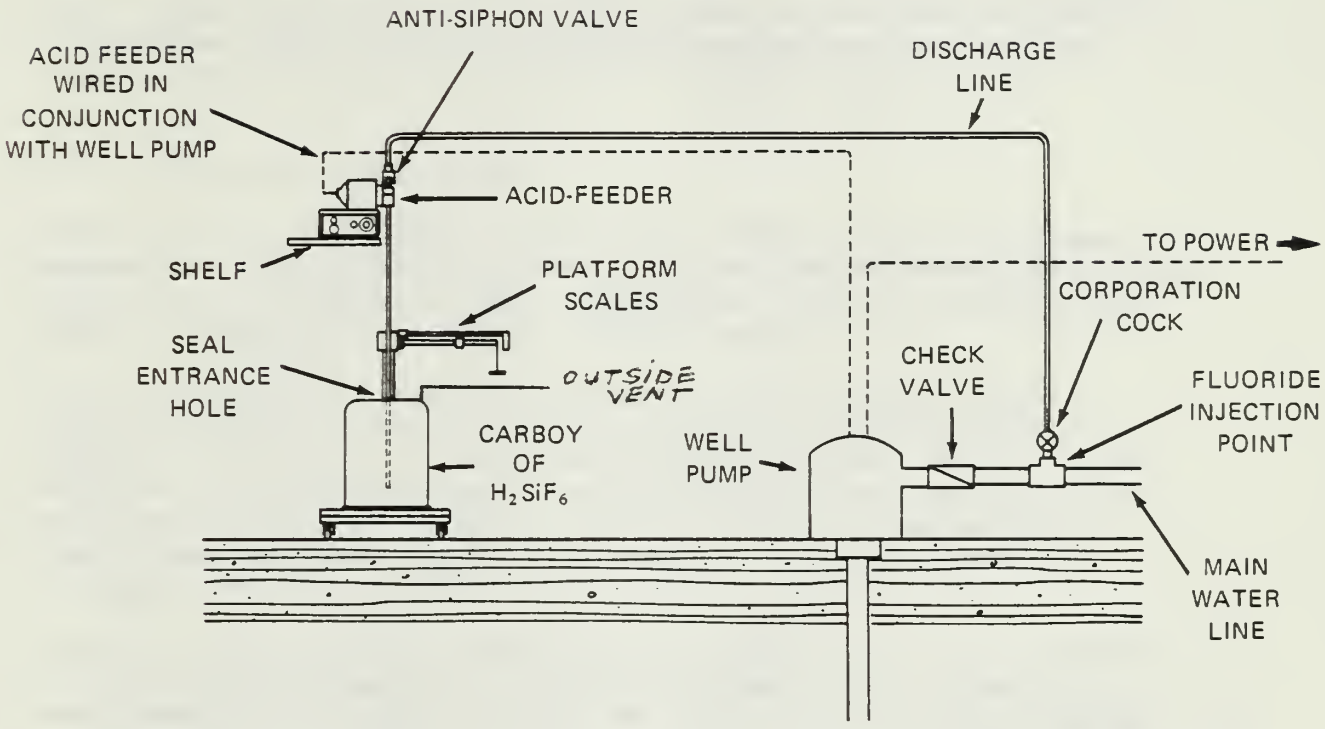
Most solution feeders come equipped with, or have available as an accessory, an anti-siphon discharge valve. This may be mounted directly on the feeder head or at the injection point. In addition, particularly if solution is to be fed into an open channel or a low-pressure pipeline, a "loaded" discharge valve should be used. This is a spring-loaded check or diaphragm valve which will not open until the feeder discharge pressure exceeds a certain fixed valve. A common setting is about 15 psi.

When mounting a solution feeder on a shelf or platform above the solution container, it is advisable to off-set it sufficiently to permit access to the container (or saturator) for filling and cleaning.

3.4.3.1 Hydrofluosilicic Acid Installation - Well

The simplest and easiest fluoride installation is an acid feed system with a well. The typical installation would include a carboy of acid, solution feeder, and an anti-siphon device. Scales could also be used. See Figure 3-2 on page 3-19.

FIGURE 3-2
HYDROFLUOSILICIC ACID INSTALLATION – WELL



3.4.3.2 Hydrofluosilicic Acid Installation - Water Treatment Plant

A more complex, but still relatively simple fluoridation installation would be when hydrofluosilicic acid is used in a larger community which has a water treatment facility. See Figure 3-3 on page 3-21.

3.4.3.3 Sodium Fluoride Installation - Saturator

The sodium fluoride saturator is a simple fluoridation system. Probably, it requires a little more space and piping than the straight acid feed, but is not considered a complex system. See Figure 3-4 on page 3-22. Both the downflow and the upflow would be designed and installed the same way. There could be some difference between the saturator used in a rural school and one used for community fluoridation.

3.4.4 Dry Feeder Installations

Only the installation of the volumetric dry feeder will be discussed because it is the typical type used. The gravimetric feeder installation would be, in essence, the same. Also, either sodium silicofluoride or sodium fluoride could be used as the dry chemical.

When installing a dry feeder, placement should be such that solution from the solution tank can fall directly into the chemical feed channel, if possible. If other considerations dictate that the feeder be placed some distance from the point of application, the drain line should be as direct as possible, with adequate slope and sufficient size to preclude precipitation build-ups and subsequent stoppages. See Figure 3-5 on page 3-23.

Obviously, the dry feeder installation must be a firm, level foundation if the scales are expected to perform satisfactorily. If there is a small hopper on the feeder, it must be readily accessible for filling, and if an extension hopper is used, it should extend vertically upward to the filling area, without angles which could trap material. For the water supply line to a volumetric feeder, there must be a section of flexible hose between the solution tank and the water pipe to permit free movement of the feeder and scale platform.

The water supply line to a dry feeder must be equipped with an air-gap or mechanical vacuum-breaker, or some other type of anti-siphon device. The air gap is the simplest and most positive protection against the dangers of a cross connection. If water pressure is too high to permit the use of an air gap, one of the other devices may be used, but in any case, the vacuum breaker must be placed between the point of entry to the feeder solution tank and any restrictive device in the pipeline, and must be installed in an elevated location.

FIGURE 3-3
HYDROFLUOSILICIC ACID INSTALLATION –
WATER TREATMENT PLANT

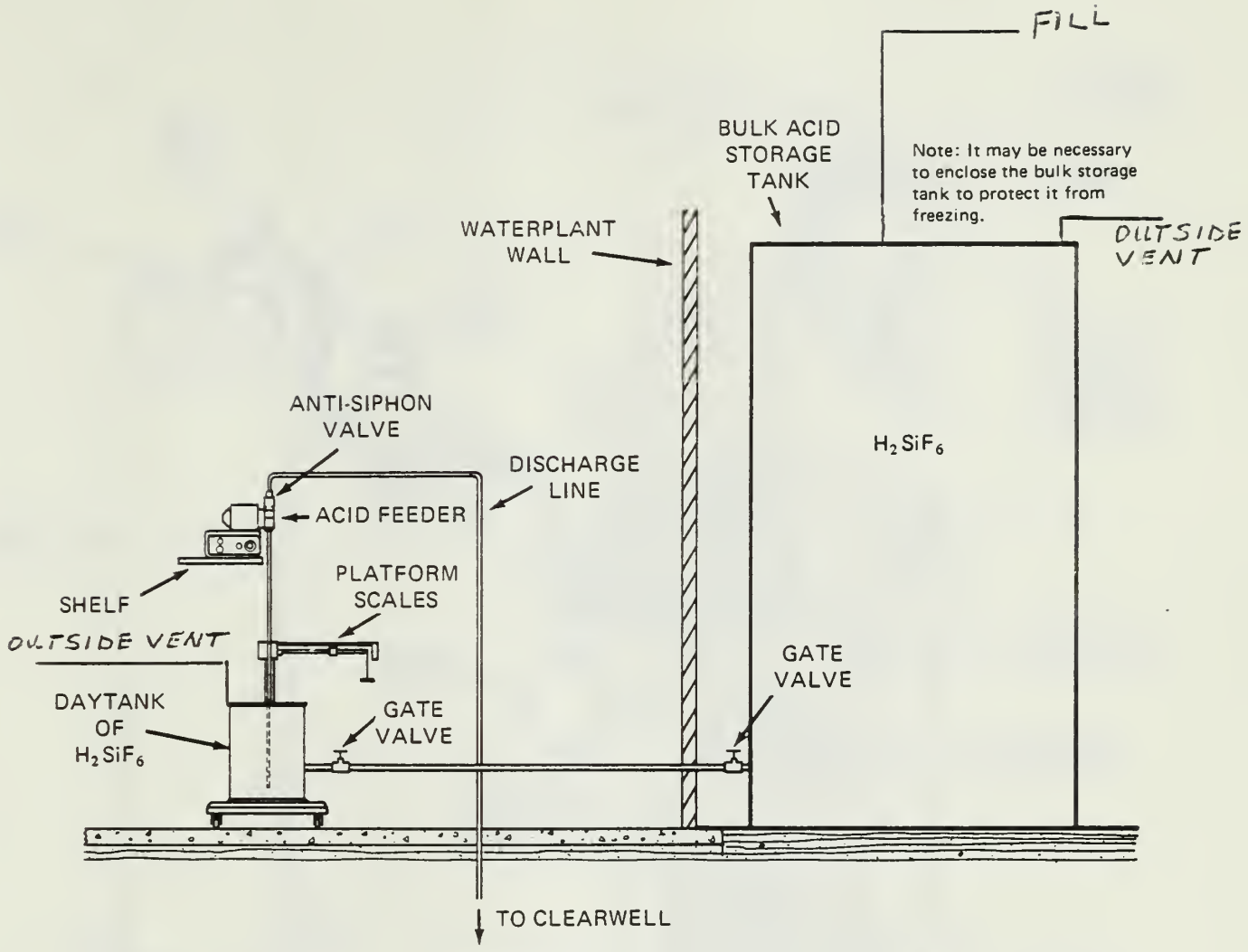


FIGURE 3-4
SODIUM FLUORIDE INSTALLATION – SATURATOR

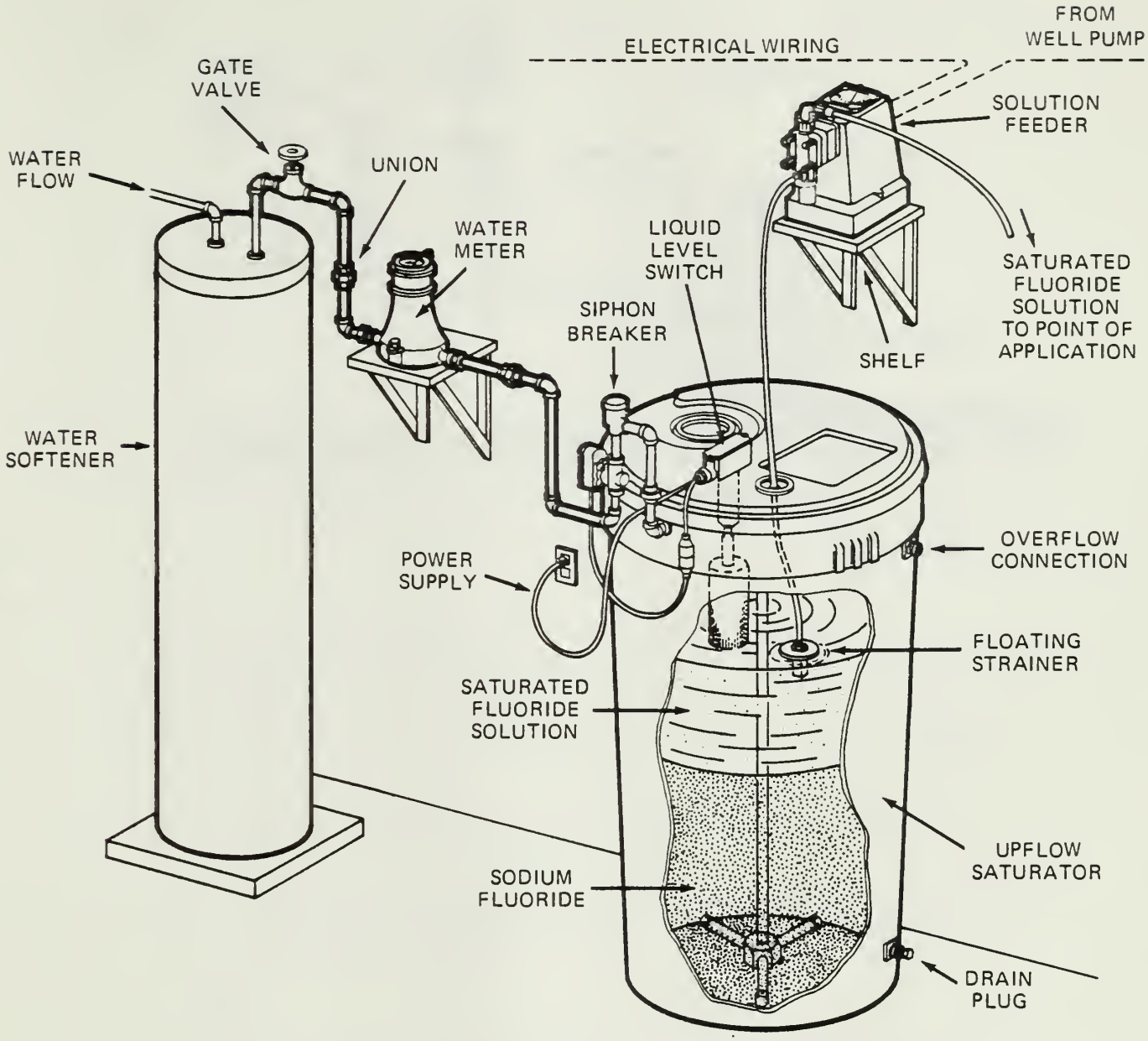
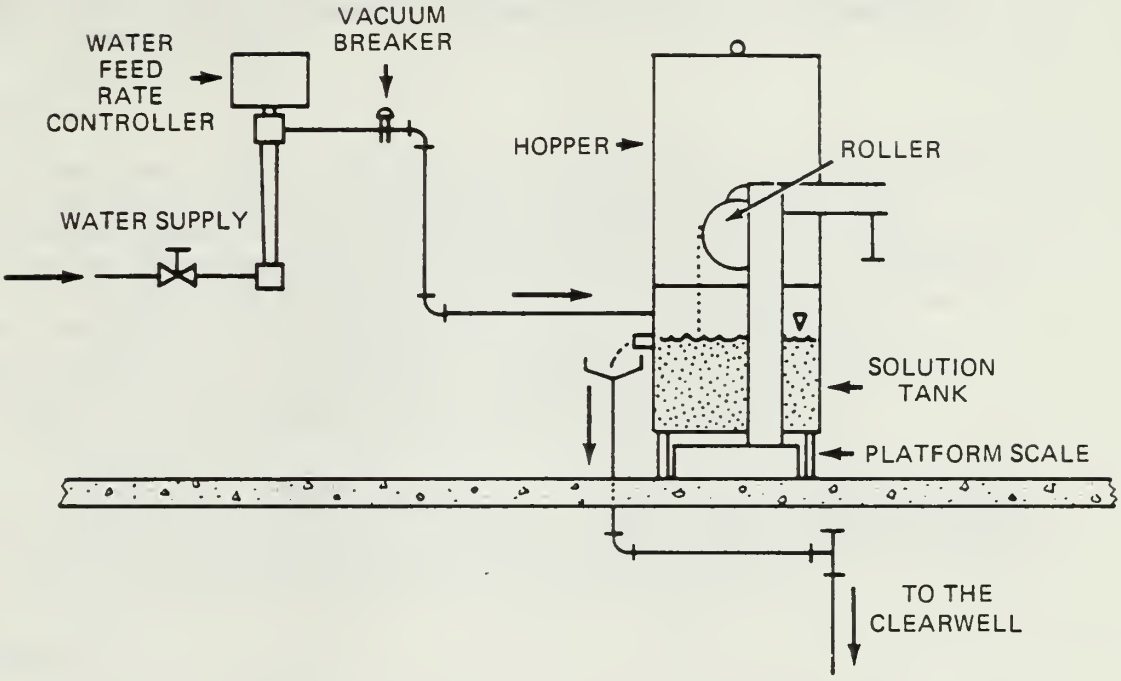


FIGURE 3-5
VOLUMETRIC FEEDER INSTALLATION



4.1 FLUORIDE ANALYSIS

(Standard Methods 414B)

Discussions:

A fluoride ion-activity electrode is used with a standard calomel reference electrode on a specific ion meter or a pH meter having an expanded millivolt scale.

Principle:

The fluoride ion- activity electrode is a specific ion sensor. Most fluoride electrodes contain a fluoride solution in contact with a laser-fluoride doped lanthanum fluoride crystal. The crystal is located at the electrode tip, contacting the sample solution as well as filling solution. The crystal acts as an ion-exchange membrane, so that when the concentration of fluoride ions in the sample is different from that of the internal standard filling solution, ions move across the crystal setting up a voltage potential which is proportional to the fluoride concentration of the sample.

Whenever a specific ion meter is used, the meter is calibrated to read fluoride concentrations directly in ppm. A calibration curve is used to relate the measured fluoride ion activity to the concentration in aqueous samples when an expanded millivolt scale pH meter is used.

Interferences:

The fluoride activity is dependent upon the total ionic strength, and hence will not respond to complexed or bound fluoride. These difficulties are largely overcome by the addition of citrate ion, which preferentially complexes aluminum up to 2 ppm and by the addition of a buffer solution of high ionic strength to swamp out variations in sample ionic strength.

Polyvalent cations such as Al(III) or Fe(III) in concentrations above 2 ppm and 200 ppm, respectively, must be removed by the preliminary distillation step. This will rarely be a problem.

The pH range must be controlled above pH 5 to prevent hydrogen ion complexation, and below pH 8 to prevent complexation with hydroxide ions. This is accomplished with a buffer.

Detection Limits:

The electrode method is capable of measuring fluoride concentration from 0.1 to 10 ppm.

The following instructions are taken in part from Orion Research Incorporated of Cambridge, MA and pertain to the Orion 409 model fluoride tester using the electrode method:

1. Before Measuring:

A. Be sure reference electrode is at least half filled with filling solution. Tip the electrode to let the solution run up the sleeve to wet the O-ring at top.

B. Make sure all plastic containers are clean and rinsed in distilled or non-fluoridated water.

C. Make sure the temperature of standards and sample(s) are equal and at room temperature. If you are unsure, use a thermometer. If you don't have one and the sample feels cold, let the samples warm up to room temperature themselves by waiting a few hours. Some laboratories warm the samples quickly by placing them in warm water.

11. System set-up

A. Checking the meter - Plug the shorting strap into the fluoride and reference electrode connectors. Set the switch to the 0.5 - 2.0 ppm position and turn the "set 1 ppm" knob. The meter is working properly if the pointer reads on-scale. Set the switch to 0.1 - 10.0 ppm and repeat the test. (check monthly)

B. Positioning the meter - The electrode support rod may be rotated forward 90^{o} so that the meter can be used lying flat on the table. In this position, the pointer may need adjusting to read exactly 1 ppm with the switch in the off position. If this is necessary, use a small screw-driver to turn the unmarked recessed screw in the center of the meter front panel.

C. Make sure the black protective cap has been carefully removed from the tip of the fluoride electrode (black).

D. Check the condition of the batteries by turning the pointer. When the batteries need replacing, the pointer will stay to the left of the area marked "BATT OK". Two 4.5 volt batteries are needed. Mallory MN - 1306, Eveready 523, or Burgess AL - 133 batteries may be used. The batteries should last about a year, and most photostores carry them.

111. Calibration

A. Use the 1.0 ppm fluoride standard furnished free by the DEQE Lawrence Experiment Station. Call (617) 682 - 5237 for refills. Prepare a 1.0 ppm fluoride buffer standard by mixing the 1.0 ppm fluoride standard in a 1:1 ratio with the buffer (TISAB).

Most water departments use 25 ml of 1.0 fluoride standard and 25 ml of buffer. A pipet must be used.

B. Place the electrode in the 1.0 ppm fluoride buffer standard. Set switch to 0.5 - 2.0 ppm position.

C. Set pointer to read 1.0 ppm on the upper meter scale (mid-point) using knob market "SET 1 ppm" after waiting three minutes (or until pointer is steady at one spot) for a stable reading. Remove electrodes from 1.0 ppm fluoride-buffer standard.

D. Prepare a 2.0 ppm fluoride-buffer standard by mixing the 2.0 ppm fluoride standard in a 1:1 ratio with the buffer (TISAB). Pipet either 25 ml of each or 10 ml of each. The 2.0 ppm fluoride standard is also available free of charge from the Lawrence Experiment Station. The buffer is not supplied by the State, but must be purchased by the user.

E. Place the electrodes in the 2.0 ppm fluoride buffer standard. Set switch to 0.5-2.0 ppm position. Set pointer to read 2 ppm on upper meter scale, using knob marked "Set 2 ppm" after waiting three minutes or until pointer is steady at one spot.

F. The meter is now calibrated and must be recalibrated each day before use. Do not use yesterdays standards!

IV. Running the Fluoride Test

A. Prepare the sample by mixing equal volumes of water sample and buffer in a plastic cup. Pipet 25 ml of sample and 25 ml of buffer, or 10 ml or sample and 10 ml of buffer.

B. Place the electrodes in the sample-buffer mixture and set the switch to the 0.5 - 2.0 ppm position. Read the fluoride level on the upper scale after waiting three minutes. If the reading is off scale switch to the 0.1 - 10 ppm scale for greater range, and read the fluoride level on the bottom scale after waiting for three minutes.

C. Prepare additional samples in a similar manner.

V. After Measuring

A. Turn switch to "OFF" to conserve batteries.

B. Leave electrodes with tips in 1 ppm fluoride-buffer solution. Do not let reference electrode dry out. See maintenance section if it dries out.

Hints For Precision Measurements

A. Keep standards and buffer tightly capped. Shake before using.

B. Never pour standards back into the bottles. Throw standards away, and prepare fresh standards daily.

C. Blot tips of fluoride electrode and reference electrode with soft tissue after each measurement to prevent contamination and carry-over.

D. The response time is better if standards and samples are slowly stirred at a constant rate by a magnetic stirrer.

E. Make sure electrode wires are connected to the meter securely, and the ends of the jacks are clean and not corroded.

Maintenance

A. Fluoride electrodes, whose response may become sluggish with time, can be restored to working order by brushing the sensing element on the flat top of the electrode with a fluoride toothpaste and a soft brush. Rinse in distilled water before using.

B. Reference electrodes should be drained and cleaned and filled with new filling solution (KCl) every six months or whenever meter drifts. If the electrode is frozen, soak in warm water until the inner sleeve is free.

C. Replace the 1.0 ppm and 2.0 ppm fluoride standards every 6-8 months, and fluoride buffer every 8-12 months. Mark the date received right on the container for future reference. Failure to follow this replacement, procedure will give wrong results.

D. The reference electrodes inner sleeve contains a silver marking (dot) which should be cleaned periodically or whenever meter drifts. To clean it, remove outer sleeve and wipe dot with a soft tissue and fine emery cloth. Then rinse in detergent water and distilled water. Do not touch it with your fingers. The end product should contain a shinny marking (dot). Then refill with filling solution (KCl) drain, and refill.

E. Orion Research may be called for free trouble-shooting information at 617 - 864-5400, ask for tech-service.

4.2 HACH METHOD

METHOD: SPADNS

RANGE: 0-2 mg/l

PRINCIPLE: (Colorimetric Method)

The fluoride analysis involves the reaction of fluoride with a dark red, zirconium lake. Fluoride combines with part of the zirconium to form a colorless zirconium-fluoride complex with the net effect of bleaching the color. Measurement (by photometer or spectrophometer) of the decrease in color intensity provides an accurate determination of the fluoride concentration.

PROCEDURE (Filter Photometer Tester)

1. Take a water sample by filling a clean 25 ml graduated cylinder to the 25.0 ml mark. Pour the sample into a clean colorimeter bottle.

2. Measure 25.0 ml of Standard 1.00 mg/l Fluoride Solution by filling another clean 25 ml graduated cylinder to the 25.0 ml mark. Pour it into another clean colorimeter bottle.

3. Pipet 5.00 ml of SPADNS fluoride Reagent into each colorimeter bottle and swirl each to mix.

4. Insert the Fluoride (SPADNS Method) Meter Scale into the meter and use the 9788 color filter. Place the colorimeter bottle that contains the prepared Standard Fluoride Solution in the light cell and adjust the light control for a meter reading of 1.00 mg/l fluoride.

5. Place the colorimeter bottle containing the unknown sample in the light cell and read the mg/l fluoride (F^-).

NOTES

A. The temperature of the standard sample and the water sample must be 20° ($\pm 1^\circ$) C or 68° F ($\pm 2^\circ$)F. If the temperatures of the standard and/or the unknown are higher or lower than 20° C, the results will not be correct.

B. In the fluoride test, the quantity of fluoride being determined is extremely small. Any fluoride test is very sensitive to small amounts of various chemicals that can interfere. Therefore, it is absolutely necessary that the colorimetric bottles and all other glassware be clean. To make sure of the accuracy of the test, it is strongly recommended that the fluoride test be repeated as a check, using the same graduates and colorimeter bottles as used above. Repeating the test will insure that the glassware is free of interfering chemicals.

C. It is advisable to mark the colorimeter sample bottles and the graduated cylinders so that they cannot become mixed.

D. The procedure given above used 1.00 mg/l Standard Fluoride Solution (available free from DEQE Lawrence Experiment Station) for standardizing the colorimeter. When routinely testing water that has a fluoride content much different than 1 mg/l, it is desirable to use a standard fluoride solution for standardization that is close to the fluoride content of the samples. For example, if the routine test samples have about 1.5 mg/l fluoride, it is recommended that a 1.5 mg/l standard solution be used rather than the 1.00 mg/l solution suggested above.

E. Chlorine interferes only in amounts greater than 5 mg/l. To remove such interference, add one drop (0.05 ml) of Arsenite Solution for Fluoride Test for each 2 mg/l (or fraction thereof) of chlorine above 5 mg/l.

F. The SPADNS method is subject to several interferences as listed below:

	Concentration		*Type of Error
Alkalinity ($CaCO_3$)	5000	mg/l	-0.1 mg/l F
Aluminum (Al^{+++})	0.1	mg/l	-0.1 mg/l F
Chloride (Cl^-)	7000	mg/l	+0.1 mg/l F
Iron (Fe^{+++})	10	mg/l	-0.1 mg/l F
Hexametaphosphate ($[NaPO_3]_6$)	1.0	mg/l	+0.1 mg/l F
Phosphate (PO_4^{---})	16	mg/l	+0.1 mg/l F
Sulfate (SO_4^{--})	200	mg/l	+0.1 mg/l F

*Error at 1.0 mg/l Fluoride

The aluminum's source is alum (if used), and the hexametaphosphate's source is phosphate (if used). The other interferences are not a problem to most Massachusetts operators.

To check for aluminum interference, read the results immediately and 1-2 hours later. If there is no difference, then practically no aluminum is present. If there is a difference, record the later fluoride reading as the most accurate result.

If it is desired to eliminate all interferences, the water sample should be distilled from an acid solution as described in Standard Methods (15th Edition - 1980) or use the electrode method (most accurate).

G. More information may be obtained from Hach Company, P.O. Box 389, Loveland, Colorado 80539 or call 1-800-257-8395 or 1-800-525-5940.

4.3 SUGGESTED TESTING PROCEDURE FOR % H_2SiF_6

By: Massachusetts Department of Public Health - 1984

1. Put on your rubber gloves and goggles or eye protection. Test when the delivery is being made or other appropriate times.

2. Carefully transfer the hydrofluosilicic acid to be tested from the sample container to a small plastic cup or container. Remember it's an acid, be careful.

3. Adjust the temperature to 60° F or 15.5° C as best you can.

4. Carefully pour the hydrofluosilicic acid from the plastic cup or container to an unmarked glass cylinder.

5. Insert the hydrometer and measure the degrees baume or specific gravity, depending on type of hydrometer you are using. The bottom of the hydrometer must not touch the cylinder.

6. Measure the degrees baume or specific gravity at the point where the surface of the hydrofluosilicic acid meets the hydrometer. Write down the reading.

7. Do not keep the hydrometer and other glassware in contact with the hydrofluosilicic acid solution any longer than necessary. Glass and hydrofluosilicic acid are not compatible.

8. Remove the hydrometer and throughly rinse the hydrometer with cool running water.

9. Pour the hydrofluosilicic acid back into the small plastic cup or container.

10. Throughly rinse the unmarked glass cylinder with cool running water.

11. Pour the hydrofluosilicic acid back into the daytank or shipping container.

12. Determine the approximate percentage of hydrofluosilicic acid from the accompaning table.

13. Experience in the field has shown that your readings are approximately up to 1% less than what the manufacturer or distributor reports to you. For example, you read 26% and the company reports 27%, that difference may be expected (The reason is the hydrofluosilicic acid is not c.p. grade with distilled water.)

Table 4-1

CONVERSION TABLE FOR HYDROFLUOSILICIC ACID (H_2SiF_6)

Degrees Baume (Be) Heavy Scale at 60° F	Specific Gravity or Density at 60° F	% Hydrofluosilicic Acid at 60° F (Concentration) By Weight
31.2	1.274	30.0
30.8	1.269	29.5
30.3	1.264	29.0
29.9	1.259	28.5
29.4	1.254	28.0
28.9	1.249	27.5
28.5	1.244	27.0
28.0	1.239	26.5
27.5	1.234	26.0
27.0	1.229	25.5
26.5	1.224	25.0
26.1	1.219	24.5
25.6	1.214	24.0
25.1	1.209	23.5
24.6	1.204	23.0
24.1	1.199	22.5
23.6	1.194	22.0

The above information is taken in part from AWWA standard B703-71 for hydrofluosilicic acid and Fisher Scientific Catalog 1983, page 513, conversion table.

NOTE: When one reads a certain percentage of H_2SiF_6, it means the higher the percentage, the higher the price. The percentage usually varies between 22-30%, as it is a by product (not waste product) in the manufacture of phosphate fertilizers.

CHAPTER FIVE STATE REQUIREMENTS

5.1 INTRODUCTION

The engineering aspects have been discussed including laboratory testing and calculations, and now all of it must be reported to the state agency responsible for surveillance. Both Departments of Public Health (DPH) and Environmental Quality Engineering (DEQE) have agreed to place the Department of Public Health as the lead agency on water fluoridation practice. This was accomplished through a formal "Memorandum of Understanding" in 1980.

5.2 DEQE RESPONSIBILITIES

DEQE is responsible to approve all new fluoride construction plans and specifications as required under the current law, and to ascertain that the maximum contaminant level (MCL) of 2.0 ppm (twice the optimum) is not exceeded under their regulations. Incidentally the MCL only applies at a consumer's tap on the distribution system and not at a well or pump station where the fluoride is added.

For more information you are referred to the DEQE "Drinking Water Regulations," 310CMR22.06 - Table 1 "Maximum Contaminant Levels for Inorganic Chemicals."

5.3 DPH RESPONSIBILITIES

DPH has five areas of responsibilities in the fluoride surveillance program which are summarized as follows:

5.3.1 DAILY RECORD KEEPING (MANDATORY)

Daily fluoride records are required to be kept by the local water works operator. For each separate fluoride injection point the following parameters must be taken and recorded.

1. Amount of water produced in gallons every day.
2. Net amount of fluoride chemical added every day in pounds.
3. Net amount of make-up water added every day in gallons or cubic feed (CF) for sodium fluoride saturators only.
4. Fluoride test results in ppm every day from a representative and approved testing tap near the fluoride injection point (usually the 100 foot out sample tap).
5. The name and strength of the fluoride compound used (usually found on shipping container or bill).

This data is recorded on the DPH form titled "Fluoridation Report" and mailed in to the Department:

Fluoridation Engineer
Department of Public Health - Rm 8M
150 Tremont Street
Boston, MA 02111

The report is due by the tenth day of the following month on a form supplied by the Department. See figure 5-1 on page 5-2

FIGURE 5-1

FLUORIDATION REPORT

Return to:

Fluoridation Engineer
DPH/Division of Dental Health
150 Tremont St. - Room [illegible]
Boston, MA 02111

City, Town, or District _____

Public Water Supply Fluoridated _____

Month of _____ 19____

Day	Gallons of Water Pumped	*Quantity of Chemical Added		Results of Fluoride Test in Parts Per Million (ppm)		Remarks (Repairs, Maintenance etc.)
		Pounds	Gal. or C.F.	Test Tap Near Point of Application	On Distribution System	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
Totals						

NOTES:

1. The Optimum Fluoride Level is 1.0 ppm.
2. This Report is Due by the Tenth Day of The Following Month at the Above Address.
3. All Fluoridated Public Water Supplies Must Be Tested Daily For Fluoride Content, But Only If Pumping.

*Circle Fluoride Chemical Used:

NaF Na_2SiF_6 H_2SiF_6

Give Purity of Fluoride Chemical _____ %
(From Shipping Container)

_____
Signature of Water or D.P.W. Superintendent

5.3.2 MONTHLY STATE CHECK SAMPLES (MANDATORY)

1. Monthly check samples of fluoridated water are required to be submitted to the DEQE State Laboratory (Lawrence Experiment Station, 37 Shattuck Street, Lawrence, MA 01843) by the local water works operator. The location of the sampling points are fixed and may only be amended with the permission of the Department of Public Health.

2. Copies of all test results are sent to the local water works operator within two weeks of receipt.

3. If any samples for a particular month are not submitted, then the operator must submit two complete sets of samples the next month, taken at two week intervals.

4. It is the responsibility of the operator to keep himself supplied with the 2 oz. (plastic containers) which are available from the lab.

5. Call the lab at 617-682-5237 if you do not receive the empty containers by the fourth week of every month.

5.3.3 QUARTERLY PROFICIENCY TESTING PROGRAM (VOLUNTARY)

1. Quarterly samples of fluoridated water (0-2 ppm fluoride) are mailed to all operators who have agreed to participate in the program. Presently everyone has joined. The operator tests each of the two samples of water for fluoride content using their fluoride tester and state supplied 1 and 2 ppm fluoride standards.

2. Their results are submitted to DPH within 30 days of receipt of the samples. Their results are compared to official Lawrence Experiment Station results and tabulated in graph form. Copies of all results statewide are compiled and sent to all interested parties. Results are coded by number to protect confidentially of the operators.

3. The purpose of the proficiency testing program is to insure all fluoride testers are in proper working order.

Bailus Walker, Jr., Ph.D., M.P.H.
COMMISSIONER

The Commonwealth of Massachusetts
Department of Public Health
600 Washington Street
Boston 02111

September 1983

5.3.4

FLUORIDE AWARD FOR 1983

For calendar year 1983 the Department will award under the auspice of the Massachusetts Dental Society a "Certificate of Recognition" to five fluoridating systems. This is our way of saying thanks to you for maintaining optimal fluoride levels in your community water system.

The Department will give points for the following fluoride activities and after all the points are added up, the five with the most points will be recognized. In case of any ties then six awards will be given. It is anticipated to make this award process an annual event.

Activity	Points	Perfect Point Score
1) Each quarterly lab proficiency test result rated excellent -2 samples per quarter are received	5	2 x 4 x 5 or 40
2) Each state lab monthly average (nearest 0.1ppm)x10. If no samples are submitted for a particular month then no points are awarded that month. (Maximum points per month = 10)	10	12 x 10 = 120
3) Each set of "Report on Fluoridation" submitted to DPH on time no later than 10th (business) day of following month	1	12 x 1 = 12
4) Water supply cross connections protected continuously-judged by DPH inspections (either pass or fail)	10	1 x 10 = 10
5) Someone on the water staff holds a certificate for completing a DPH two-day course in water fluoridation (Maximum of 1 person)	18	1 x 18 = 18
Perfect Total Score		200

An example is given for community XYZ:

Activity				Point Score
1) Only 5 out of 8 samples were rated excellent				5 x 5 = 25 points
2) The monthly fluoride averages were:				
January	0.9	July	1.1	9 + 10 + 10 + 10 +
February	1.0	August	1.0	10 + 10 + 10 + 10 + 10
March	1.0	September	1.0	+ 8 + 9 + 10 = 116 points
April	1.0	October	.8	
May	1.0	November	.9	
June	1.0	December	1.0	
3) Every report except for May was received by 10th (business) day of the following month				11 x 1 = 11 points
4) Yes, the anti-siphon valve was installed on the fluoride metering pump at both wells				10 points
5) The chief operator and assistant chief operator both were awarded a certificate for attending a DPH training course.				18 points
Total:				180 points

Bailus Walker, Jr., Ph.D., M.P.H.
Commissioner
Department of Public Health

5.3.5 FLUORIDE INSPECTIONS

All fluoridating sites are inspected periodically by the DPH, to insure that the equipment is in working order. There are a total of approximately 200 separate fluoride injection sites in Massachusetts.

Sanitarians from the four DPH regional offices conduct inspections on a quarterly basis which consists of site visits and field testing of water for fluoride content. The fluoride engineer also conducts annual inspections.

Whenever a DPH official visits a fluoridating system, an official inspection report tittled "Fluoridation Inspection Report" is completed and given to an official of the system. See figure 5-2 on page 5-7.

A copy of the report is distributed to the fluridation engineer, regional sanitarian, and the appropriate DEQE regional office.

Figure 5-2

The Commonwealth of Massachusetts

Department of Public Health

Division of
Community Sanitation
727-0732

150 Tremont Street
Room 8M
Boston 02111

FLUORIDATION INSPECTION REPORT

CITY OR TOWN: _____

DATE: _____

OFFICIAL: _____

1. Public Water Source: _____
2. Operator or Superintendent: _____
3. Injection: Saturator Dry Feed Liquid Feed
4. Chemical: Sodium Fluoride Sodium Silico-Fluoride Hydrofluosilcic Acid
5. Fluoridator Working: YES ____ NO ____
6. Make-Up Water Softener Present: YES ____ NO ____
7. Make-Up Water Metered: YES ____ NO ____
8. Cross Connections Protected: YES ____ NO ____
9. Make of Feeder Pump: _____
10. Feed Pump Setting: Belt: ____ Cycle: ____ Sec. On: ____ Sec. Off: ____
11. Rate of Water Flow: _____ MGD, GPM, GPH
12. Test Results: _____ P.P.M.
13. Method Used: Electrode Colorimetric
14. Preceding Monthly Fluoridation Report Submitted to Dept. of Public Health:

    YES ____ NO ____
15. Remarks: _____

_____

_____

The Recommended Optimum Fluoride Level for Fluoridating Systems is 1.0 P.P.M. With a Permissible Variation of 0.1 P.P.M. Below the Optimum or 0.3 P.P.M. Above.

_____
Signature of Public Health Official

cc: DEQE Regional Office